With the compliments of
F. C. Greene

MISSOURI BUREAU OF GEOLOGY AND MINES
ROLLA, MO.
H. A. BUEHLER, Director and State Geologist

VOL. XIII, SECOND SERIES

The Stratigraphy of the Pennsylvanian Series in Missouri

BY
HENRY HINDS and F. C. GREENE

WITH

A Chapter on Invertebrate Paleontology

BY G. H. GIRTY

Surveyed in Co-operation with the United States Geological Survey

1915

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ENGRAVED MAP.

LETTER OF TRANSMITTAL.

Missouri Bureau of Geology and Mines,
Rolla, Mo., October 13, 1914.

To the President, Governor Elliott W. Major, and the Members of the Board of Managers of the Bureau of Geology and Mines:

Gentlemen:—I have the pleasure of transmitting herewith a report upon the stratigraphy of the Pennsylvanian series in Missouri, by Henry Hinds and F. C. Greene, the work being done in co-operation with the U. S. Geological Survey. Chapters IV, V, and the bibliography were prepared by Mr. Greene; the remaining chapters are the result of joint authorship. The paleobotany is discussed by David White, and the invertebrate fossils are made the subject of an exhaustive chapter by Dr. Girty.

This report supplements volume XI, which deals primarily with the coal deposits, their extent, thickness, stratigraphic relations, and development. In the present volume more space is devoted to the formations which contain little or no coal, and especially to those in the Missouri group, which were examined in the field by Mr. Greene. Most of the field work was done in connection with the preparation of the report on coal, but detailed mapping in the Leavenworth quadrangle by Hinds, Greene, and M. Albertson late in 1911; in the Smithville, Green City, and Queen City quadrangles by Greene and Albertson in 1912; and in Grundy and Mercer counties by Greene and Albertson in 1913, added to the store of information obtained.

In doing the field work the various limestones were traced, where possible, across Missouri from Kansas to Iowa and correlations made with the adjoining states. The divisions and names used are chiefly those published in vol. 9 of the reports of the University Geological Survey of Kansas. Except in cases where complete correlation has not been made, most of these divisions have been adopted by the neighboring states. The

Iowa Geological Survey will use the names and divisions as designated in this report with the exception of the term Drum. In Iowa, what is thought to be the same limestone has been designated the De Kalb. If these members are found to be equivalent, when complete correlation is made, the term De Kalb must be retained. The Nebraska Geological Survey will use the term Burlingame for the limestone supposed to be the same as the Tarkio. The exact equivalence of these two limestones has not as yet been determined. The interval included in the Kanwaka, Lecompton, and Tecumseh members in this report has not been divided into three members in Nebraska as it has in Kansas and Missouri, and the larger unit name ("Platte") will be retained. With these exceptions, the scale is adopted in Nebraska.

Respectfully submitted,

H. A. BUEHLER,

Director and State Geologist.

ACKNOWLEDGMENTS.

The vast amount of literature dealing with the Missouri Pennsylvanian has been freely drawn upon, with acknowledgments, in the preparation of this report. The writings of G. C. Broadhead, C. J. Norwood, C. F. Marbut, Arthur Winslow, C. H. Gordon, E. Haworth, John Bennett, and G. L. Smith have been of especially great assistance. To David White the writers are under obligation for the identification of fossil plants and general supervision of the work. G. H. Girty identified the invertebrate collections and has contributed a chapter on paleontology. M. Albertson assisted in the field work for three seasons and M. E. Wilson for one season; to both of them the writers are under obligation. Mr. Hinds' field work was continued through two field seasons and Mr. Greene's through four seasons.

Fig. 1. Map of Missouri showing areal distribution of Pennsylvania series. Dense shading shows outcrop of Missouri group; light shading, outcrop of Des Moines group.

The Stratigraphy of the Pennsylvanian Series in Missouri.

By Henry Hinds and F. C. Greene.

CHAPTER I.

THE PENNSYLVANIAN SERIES IN MISSOURI.

LOCATION AND IMPORTANCE.

The main body of the Pennsylvanian series includes the highest consolidated rocks in about 24,000 square miles of northern and western Missouri (see fig. 1). In addition there are a number of small outliers and pockets in central Missouri and on the Ozark plateau that are too small to be shown on the accompanying sketch map. This series is of great economic importance because of the deposits of coal, shale, clay, and stone that it contains, and it also presents many problems that are not lacking in scientific interest.

GENERAL RELATIONS.

The Carboniferous system of the United States is now commonly considered to consist of three series: the Mississippian at the base, the Pennsylvanian in the middle, and the Permian at the top. The Mississippian of Missouri contains a very large proportion of crystalline limestone, in strong lithologic contrast to the Pennsylvanian, in which shale is preponderate, sandstone is common, and the limestone is chiefly of the fine-grained type. The two series are separated by a wide-spread unconformity. The Permian series does not differ markedly from the Pennsylvanian, but has not been found in Missouri.

The Pennsylvanian series in Missouri is composed of about 1,900 feet of shale, sandstone, limestone, clay, and coal. It is the only formation containing commercially important coal beds and the youngest consolidated formation in the area in which it outcrops. It includes beds that are contemporaneous with the upper part of the Pottsville, the Allegheny, the Conemaugh, and the lower part of the Monongahela formations of the Appalachian region. In Missouri and adjacent portions of neighboring states the Pennsylvanian series is subdivided as in figure 2.

The dominant structural feature of Missouri is the Ozark uplift in the southern part of the State. In the Ozarks the early Paleozoics lie at relatively higher levels than elsewhere and younger beds that may have formerly covered the region have been in greater part removed by erosion (see State geologic map in pocket). Strata dip away from the Ozarks to the west, northwest, and north, so that in those directions successively younger rocks appear at the surface. These dips are nowhere steep, but are greater near the Ozark border than at a distance from it. In the area occupied by the main body of the Pennsylvanian south of Missouri River the dip is very gently northwest; in northwestern Missouri it is westerly, and in north-central Missouri strata lie nearly level when broadly considered, the horizontality being disturbed only by small cross anticlines from northwest to southeast.

The small outliers of probable Pennsylvanian in the Ozarks lie on rocks of various ages, but chiefly on late Cambrian or early Ordovician. The main body of the Pennsylvanian in western and northern Missouri lies, so far as known, upon Mississippian rocks, except in a few places near the Ozark border. The Mississippian rocks upon which the Pennsylvanian rests range from St. Louis limestone in northeastern Missouri to limestone of Burlington age in the central and southwestern parts of the State. North of Missouri River the Pennsylvanian outcrops chiefly at intervals in the valleys or along partially buried escarpments of resistant rock, the series being largely concealed by a mantle of glacial drift, accompanied in places by windblown loess.

TOPOGRAPHY.

RELIEF.

That portion of Missouri in which the main body of Pennsylvanian rocks outcrops lies at a lower altitude and has less relief than any other portion of the State except the Southeast Lowlands—a part of the Gulf Coastal Plain. The Pennsylvanian area is lowest in the vicinity of St. Louis and highest in the district between Aurora and Springfield, though small outliers lie at still higher levels in the Ozark plateau.

The surface of the area in which the Pennsylvanian is the highest consolidated formation ranges between 700 and 1,100 feet above the sea, rising from east to west. The highest altitudes are

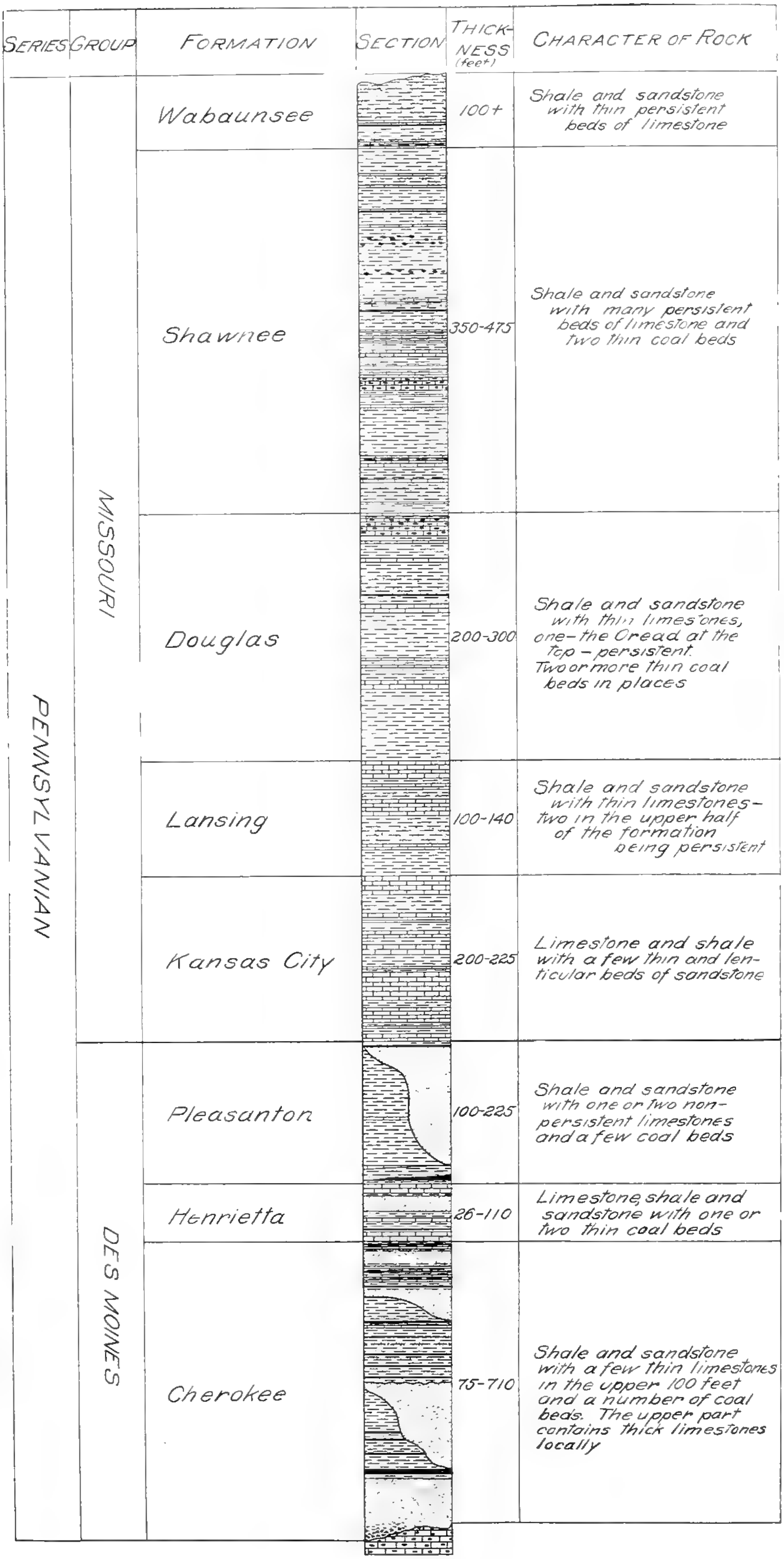

Fig. 2. Generalized columnar section of the Pennsylvania series in Missouri.

attained in southern Jackson and northern Cass counties (maximum 1,140 foot), on the divide in southern Clay and Platte counties (maximum 1,080 feet), on the divide between Platte and Grand rivers (maximum 1,100 feet) and on the divide between Platte and Missouri rivers (maximum 1,100 feet). The greatest local relief is along the escarpment formed by the limestones at the base of the Kansas City formation and along Missouri River. At a point about midway between Iatan and Weston, in Platte County, the river bluff rises 340 feet above the flood-plain in one-eighth of a mile, but such notable relief is not known elsewhere in the Pennsylvanian area of the State.

DRAINAGE.

By far the greater part of the drainage of the Pennsylvanian area of the State is tributary to Missouri River, though a comparatively small area along the northeastern edge drains directly into the Mississippi. The principal streams south of Missouri River are the Osage and Blackwater which, in the Pennsylvanian area, have a general easterly direction, but the northeast and southeast flowing tributaries cause the outcrop of any particular formation to assume a dendritic form. The streams are, as a rule, wide-bottomed and with low bluffs where cutting through shale, but the valleys are slightly narrower and more steep-sided where there are one or more thick layers of limestone. Where the streams enter Mississippian rocks the valleys narrow and the meanders are deeply intrenched.

North of the Missouri the principal tributaries are, from west to east, the Nishnabotna, Tarkio, Nodaway, Platte, Grand, and Chariton, most of them flowing in a general southerly direction. The existence of this great number of south-flowing streams is probably due to the initial slope of the drift surface, as most of the streams of northern Missouri appear to be postglacial. The flood-plains are wide and the bluffs low where the streams are cutting through drift, but the valleys are narrower and steeper where cut in indurated rocks. The change in the shape of the valleys where the streams flow from glacial material to indurated rocks is well shown on the two forks of Grand River north of Trenton and on the Chariton north of Connelsville. In the discussion of the stratigraphy of northern Missouri mention is more frequently made of outcrops on the south sides of streams than on the north sides. Steep bluffs on the south sides and gentle slopes on the north are characteristic of the valleys in this part of the State. Similar asymmetrical valleys are also common in Iowa and other drift-covered regions and were attributed by Calvin to the disintegration and loosening of material on the south-facing slopes by frequent alternations of freezing and thawing during the winter months.

PHYSIOGRAPHIC DIVISIONS.

Missouri contains four principal physiographic divisions that are more or less distinct: (1) the Drift Plains, (2) the Scarped Plains, (3) the Ozark Region, and (4) the Southeast Lowlands (a part of the Gulf Coastal Plain).[1] These are shown in figure 3.

The southern boundary of the Drift Plains is not definite. In this division the topographic forms, with few exceptions, are those produced by erosion of the nearly level surface of the Kansan drift sheet. East of Chariton River the upland is characterized by "tabular divides" and west of that stream by hilly or rolling topography.

The Scarped Plains consist of plains bounded by escarpments produced by erosion of Pennsylvanian strata of unequal resistance. The northern half of this division is overlain by glacial drift which only partially masks the terraced effect. In a few places this mantle of drift causes the Scarped Plains to blend with adjacent parts of the Drift Plains, but the boundary can usually be determined within a few miles. The Scarped Plains are subdivided into the Lathrop, Jamesport, Warrensburg, and Nevada plains by the escarpments of the Plattsburg and Stanton, the Hertha, Bethany Falls, and Winterset, and the Fort Scott and Pawnee limestones. Other minor plains and escarpments occur both in the Scarped Plains and in adjoining areas, but these are not considered of sufficient importance to warrant special mention in a state-wide classification.

South and east of the two main divisions just mentioned is the Ozark Region, occupying most of the south-central portion of the State. It is a region of higher altitude and older outcropping formations than the other physiographic divisions. Most of the streams flow through valleys with incised meanders. The Ozark Region is subdivided into the Springfield Plain and the Ozark Plateau. The surface of the Springfield Plain, as a whole, is smooth except near the larger streams and is upheld chiefly by Mississippian limestones. The Ozark Plateau is distinguished from the bordering plain by its greater dissection. Since there

[1]In this discussion Marbut's terms used in "Physical features of Missouri," Missouri Geol. Survey, vol. 10, pp. 14-109, 1896, are adopted in part.

Fig. 3. Map of Missouri showing physiographic divisions.

are only very small patches of Pennsylvanian rocks on the Plateau, mention of minor features is not considered essential in this report.

The remaining main division, lying southeast of the Ozark Plateau, is the Southeast Lowlands, a part of the Gulf Coastal Plain. This area is one of low altitudes and very little relief. It is the only physiographic division in which there are no Pennsylvanian rocks.

PHYSIOGRAPHIC EFFECTS OF GLACIATION.

North of Missouri River, a few escarpments appear in the river counties, but over the greater part of northern Missouri the drift averages 50 feet thick in the south and 200 to 400 feet near the Iowa line, and effectually conceals preglacial features. The preglacial surface of north Missouri consisted of escarpments and structural plains much like those south of the river at the present time. These features are now largely obliterated by a drift mantle in the Drift Plains. The Hertha-Winterset escarpment, probably never completely eradicated, has been partially resurrected by the removal of drift by Grand River and its tributaries. Along Missouri River and the lower courses of its tributaries short escarpments formed by the Plattsburg and Stanton, Iatan, Oread, Deer Creek, and Tarkio limestones have been in part resurrected and in part accentuated by postglacial erosion. The Jamesport and Lathrop platforms probably have much the same appearance as before glaciation.

The surface left by the ice sheets slopes, in general, southeast or south and the main streams of the area may have had their courses determined by this inclination. In the western half of north Missouri the country is rolling, but farther east the divides are tabular and the valleys comparatively narrow. Where the streams have cut into preglacial uplands and exposed consolidated rocks they flow through comparatively steep-sided, narrow valleys; where the present streams cross preglacial lowlands or valleys the slopes are gentle and there are few outcrops of the older formations.

GENERAL DESCRIPTION OF SERIES.

THICKNESS.

The Pennsylvanian rocks of Missouri have a general dip to the northwest and west and are, consequently, thin along their eastern border, where only the older formations have been spared by erosion, and thickest in the northwestern counties of the State. Since dips are low and surface relief small, outcrops of the highest and lowest beds are separated by distances of more than 100 miles. From outcrop observations alone, the thickness of the Pennsylvanian in any locality not on its border can be determined only by using the thicknesses of the lower formations that were determined in their outcropping areas at what may be considerable distances. This method does not yield exact results, however, for drilling shows that many of the shale members of the Missouri group thin to the northwest and that the Des Moines group varies within wide limits because of irregularities in the floor upon which it rests.

By adding the thickness of Pennsylvanian rocks penetrated by the Forest City drilling to the younger formations outcropping farther up Missouri River, the total thickness of the series is determined to be about 1,900 feet. The Nebraska City, Nebraska, drilling shows, however, that the Des Moines group overlaps toward the northwest and is much thinner there than at Forest City. It is probable, therefore, that the maximum thickness of the Pennsylvanian at any one place in northwestern Missouri is not more than 1,700 feet. South and east of Atchison and Holt counties, the thickness decreases because of the absence of the younger formations.

SUBDIVISIONS.

The Pennsylvanian series in Missouri has been divided into two groups, the lower termed the Des Moines group and the upper termed the Missouri group (see fig. 2). This was originally done chiefly in the belief that the Missouri group was strongly differentiated by a greater abundance of calcareous material. It is true that the lower part of the Missouri group contains many exceptionally thick beds of limestone and that the upper part of the Des Moines group is comparatively free from them, yet there are several thick formations in the upper group that are as free from limestone as any in the lower. Nevertheless there is a well-marked faunal break between the two groups that perhaps justifies their separation, and for economic purposes the Missouri is distinguished from the Des Moines by the absence of important coal beds.

There are strong indications of a wide-spread unconformity within the Pleasanton formation, and it may be that the faunal break mentioned above is due to this feature. If this is so, the boundary between the two groups should be drawn at the unconformity and within the Pleasanton. In much of the State, however, it would be impossible to accurately map such a boundary in the field. It is to be hoped that additional paleontologic evidence may result in the near future in a new subdivision of the Pennsylvanian into groups correlative with those in the Appalachian region. It is fairly certain that the lower part of the Cherokee shale is of Pottsville age and the upper part is of Allegheny age. From incomplete collections already made it is tentatively suggested that Allegheny time ends at the horizon of the unconformity in the upper part of the Pleasanton formation and that Conemaugh time ends well up in the Shawnee formation.

The two groups include eight formations, three in the Des Moines and five in the Missouri. The formations are in turn divided into units termed members.

SUBDIVISIONS OF THE PENNSYLVANIAN SERIES IN MISSOURI.

Group.	Formation.	Member.	Bed.
Missouri......	Wabaunsee formation..	Undifferentiated......... Tarkio limestone.........	....
	Shawnee formation.....	Scranton shale........... Howard limestone....... Severy shale............ Topeka limestone........ Calhoun shale........... Deer Creek limestone..... Tecumseh shale......... Lecompton limestone..... Kanwaka shale..........	
	Douglas formation.....	Oread limestone......... Lawrence shale.......... Iatan limestone.......... Weston shale............	.... Amazonia limestone (toward top). ....
	Lansing formation.....	Stanton limestone........ Vilas shale.............. Plattsburg limestone..... Lane shale..............	.... Farley limestone (in middle).
	Kansas City formation.	Iola limestone........... Chanute shale........... Drum limestone......... Cherryvale shale......... Winterset limestone...... Galesburg shale.......... Bethany Falls limestone.. Ladore shale............ Hertha limestone........	.... Raytown limestone (toward top). Cement City limestone (near base). ....
Des Moines...	Pleasanton formation...	Undifferentiated.........	....
	Henrietta formation....	Pawnee limestone........ Labette shale............ Fort Scott limestone.....	....
	Cherokee shale........	Undifferentiated.........	....

LITHOLOGY.

The Pennsylvanian series is composed of a number of varieties of shale, sandstone, limestone, clay and coal. It is unique among Paleozoic units in the variety of its sediments and in vertical variability. Some of the shale and sandstone beds are more than 50 feet thick, but more commonly there is a change of sedimentary types every 20 feet or less vertically. The thickest limestone beds, the Iola at Kansas City and one in the upper part of the Cherokee near Fulton, are 40 feet thick, but this is exceptional. Some of the most persistent limestones average little more than two feet in thickness.

The shales are the most important, quantitatively, of any of the rock varieties and constitute a considerable proportion of every formation. The common type is bluish-gray and argillaceous—rarely without some mica and sand; it is the "soapstone" of drillers. At certain more or less persistent horizons the shale is reddish or purple, variegated with a light cream or greenish tint, and is wholly free from sand or mica. In the lower part of the Cherokee the shale at many horizons grades vertically or horizontally into dark or black shale that breaks down more readily on exposure and lacks the firmness of the slaty shale found associated with the coal and limestone beds of higher strata. The slaty shale is commonly black, and is so fissile as to resemble true slate, a rock it is erroneously considered to be by miners, drillers, and many others. Some of the shales are calcareous, in places containing much lime as a cementing material or as impure lenses and concretions. Some shales grade both laterally and vertically into sandstones and often it is merely a matter of personal opinion as to whether a bed should be called shale or sandstone.

The sandstones vie with the shales in importance, quantitatively considered. In color they vary from white, blue, and gray to brown and red, but commonly weather to a yellow or reddish brown. As a rule they are micaceous and medium-grained, but in a few instances are coarse-grained and non-micaceous. They have been found containing so much calcareous material that it was a question whether to call them calcareous sandstones to sandy limestones.

The limestones are commonly light-colored, fossiliferous, fine-grained, compact, and more or less shaly along the bedding planes. Many of the beds, especially the thicker ones, are cherty; some are oölitic and thick-bedded, as the Drum at Kansas

City and the Bethany Falls at Trenton and Princeton; and others are made up of small fragments of bryozoans, shells, and other invertebrate remains. Certain beds, such as the "Chaetetes limestone" in the Cherokee shale, the upper part of the Fort Scott limestone, and the Pawnee limestone in Bates County, seem to have been in part ancient coral reefs. A macroscopically crystalline appearance is rare and is largely confined to brachiopod shells, mainly of the genus Composita or Seminula. Other varieties of limestone deserving special mention are the thin, dark-gray or blue, even-bedded deposits such as parts of the cap rocks of the Summit, Mulky, and Tebo coals and the middle part of the Oread limestone, the gray or blue "bottom-rocks" of coal beds, commonly nodular and uneven on their upper surface, and the "conglomerate" or "brecciated" unfossiliferous beds like the Iatan and Bethany Falls limestone at their type localities and some of the "bottom-rocks."

The coal is of the cannel and bituminous varieties, the latter by far the more common. Cannel is not uncommon in the pockets in and near the Ozark region. The coal beds of the upper part of the Cherokee shale and of the Henrietta formation are in many cases associated with limestones and are characterized by an abundance of white gypsum and calcite scale in the joints. The "red" coals, so much esteemed by certain domestic consumers, owe their color to the staining of this scale by iron rust resulting form the decomposition of the pyrite contained in the coal.

Clays are most common near the base of the Cherokee, underlying coal beds, and as thin intercalations separating limestone layers or immediately underlying limestone beds. Flint and plastic fire clays lie at or near the base of the Cherokee in Callaway and neighboring counties and in St. Louis county. Pottery and stoneware clays are found at various horizons in the lower part of the Cherokee. Nearly all coal beds are underlain by clay, commonly and often incorrectly termed "fire clay." Many deposits exhibit a slight lamination on weathering and would be called clays when moderately fresh and shales if subjected to longer exposure.

The remaining type of sediment, and perhaps the least common, is conglomerate. At the base of the Pennsylvanian, cherts—the residuum of cherty limestones that has been spared by pre-Pennsylvanian weathering and erosion—have since been cemented to form breccias or conglomerates. Some conglomerates at the base of the Pennsylvanian contain pebbles derived from older rocks. A few conglomerates higher in the section are composed chiefly of Pennsylvanian limestone pebbles in a calcareous matrix.

PREVIOUS WORK.

Because of its situation on main lines of travel from the East to the West, Missouri was visited at an early date by a number of geologists, but their published accounts are rather fragmentary. The most important of the early expeditions in the Pennsylvanian area was that of Owen[1] made in connection with classifying the public lands of Iowa and other states. Owen followed down Missouri River from Council Bluffs to St. Louis, making a number of valuable observations. He mapped the Missouri group outcrops seen above Lexington, as Carboniferous limestone (Mississippian), a mistake made also by a few other observers and definitely corrected by Swallow.

Soon after the organization of the first State Geological Survey in 1853, with G. C. Swallow in charge, systematic work was begun by reconnaissance journeys, followed by county mapping. Swallow traveled down Missouri River from Council Bluffs to Rocheport. He believed that the Missouri group dipped down the river and that practically the same strata were exposed at all points between Lexington and the northwestern corner of the State. His "Upper Coal Series," essentially the same as the Missouri group, is consequently only 262 feet thick, an error of about 880 feet in outcrop observations. Major F. Hawn made an examination of a strip extending across the State near the line of the Hannibal and St. Joseph Railroad, noted the important coal beds of north-central Missouri, and constructed a generalized vertical section that is correct in part. A few other excursions were made in coal-bearing territory, but the results were not published. In 1854 Swallow completed brief surveys of Marion and Cooper counties, while F. B. Meek worked in Moniteau and B. F. Shumard in St. Louis County. It is interesting to note that Meek recognized the true nature of the Ozark coal pockets at even this early date. The results of this work were published as the First and Second Annual Reports of the Missouri Geological Survey.

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[1]Owen, D. D., Rept. of the Geol. Survey of Wis., Ia., and Minn., etc., 1852

The outbreak of the Civil War caused the suspension of the first Survey in 1861, before the results of its later work could be published. The second Survey was organized in 1870 and published in 1872 the reports of the work done just previous to 1861, including descriptions of the geology of Shelby, Macon, and Randolph counties by G. C. Broadhead, of Miller, Morgan, and Saline by F. B. Meek, and of Crawford and Clark by B. F. Shumard. These reports, though brief and as a rule unaccompanied by adequate maps, marked a distinct advance over earlier work. In the report of field work done in 1872 under Raphael Pumpelly, W. B. Potter described the Lincoln County coal pockets and Broadhead the geology of Livingston, Clay, Platte, Buchanan, Holt, Atchison, and Nodaway counties. Broadhead also reported on the country between Sedalia and Kansas City and gave a general description of the remainder of the Pennsylvanian area. In connection with this he made a generalized section of the "Upper Coal Measures" that is accurate in the main, and a condensed section of all the coal beds that is considerably in error in the lower part.

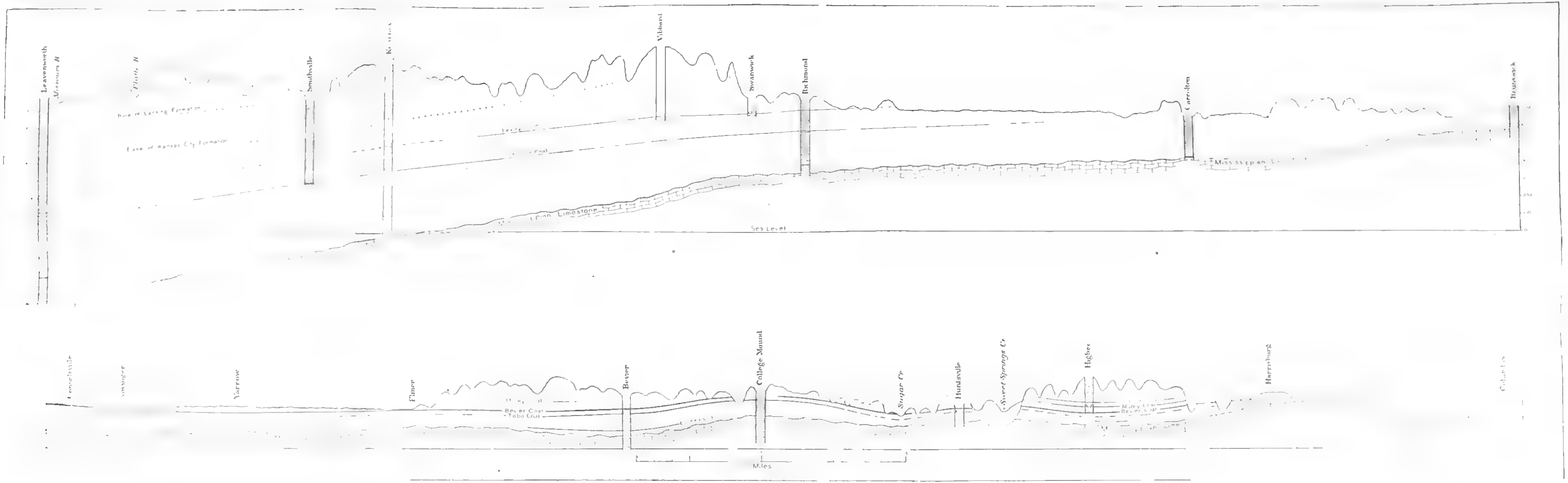
In the report of the field work of 1873 and 1874, Broadhead, who was then State Geologist, published a good but much generalized section of the southwest coal field and county reports on Cedar, Bates, Sullivan, Adair, Linn, Andrew, Daviess, and Cole counties, and described Jasper, Barton, Vernon, and Howard counties in collaboration with C. J. Norwood. At the same time Norwood also described Putnam and Schuyler counties. The second Survey was abolished in 1876.

The Missouri Bureau of Geology and Mines was organized in 1889 under Arthur Winslow, one of whose first publications was a brief preliminary report on the coal deposits of the State. Detailed geologic and topographic mapping was soon begun on the quadrangle system and reports published on the Higginsville quadrangle by Winslow, on the Bevier by C. H. Gordon, and on the Huntsville, Richmond, Lexington, Calhoun, and Clinton quadrangles by C. F. Marbut. In accuracy and completeness these surveys were distinctly in advance of many of their contemporaries. The nomenclature used in the later reports forms the basis for that of the Des Moines group in this volume, with the modifications necessitated by the correlations recently established between the areas then mapped and between Henry County and Kansas.

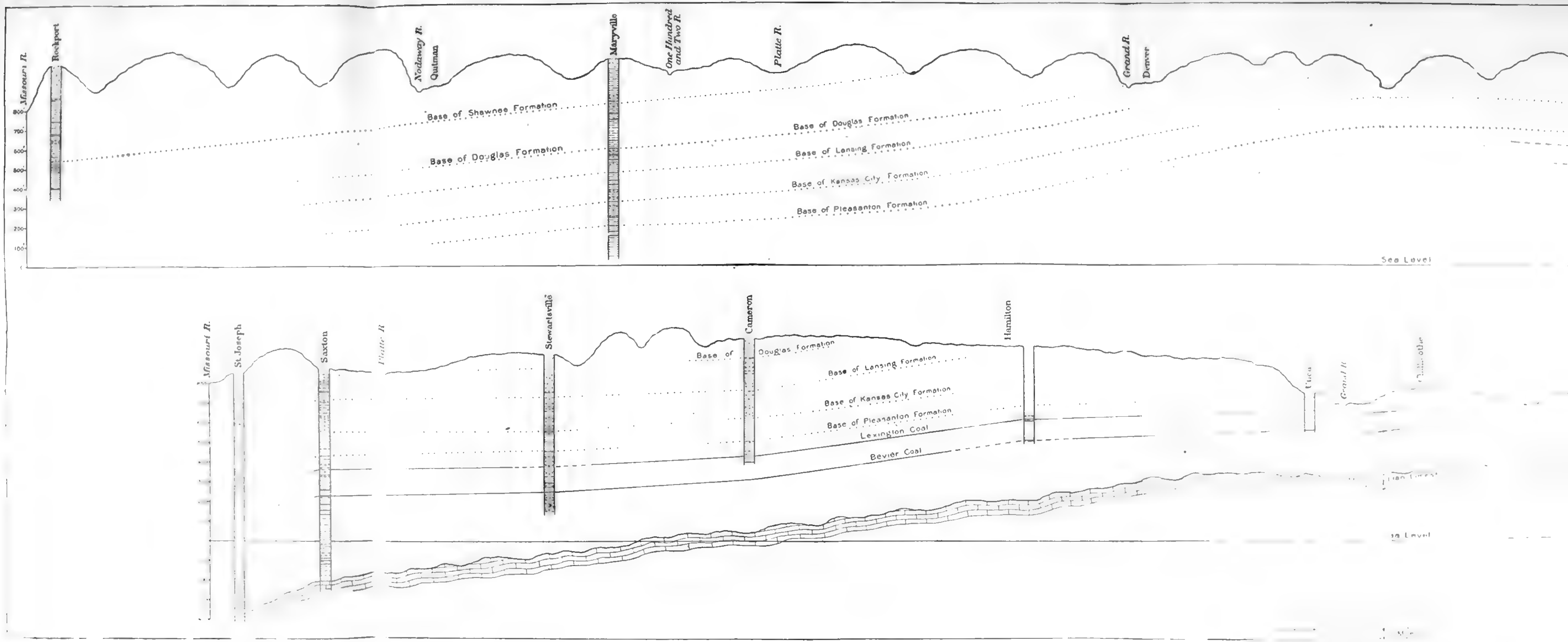
With the exception of a few detailed areal descriptions which mention very small coal pockets and Pennsylvanian outliers, all reports published during the last 20 years deal only indirectly with Pennsylvanian stratigraphy or confine themselves to one or more of the economic resources. In 1895 Broadhead published a short general discussion of the "Coal Measures," but it contributed little that was new. Discussions of the physiography and topography of the State by Marbut, of the paleontology by C. R. Keyes, and of the Quaternary deposits by J. E. Todd covered parts of the Pennsylvanian area. Two bibliographies, one by F. A. Sampson in 1890 and another by Keyes in 1896, cited all the Missouri geologic literature known at those dates. The economic reports covered the entire State and included that on clays and shales by H. A. Wheeler in 1896, that on the quarrying industry by E. R. Buckley and H. A. Buehler in 1904, that on lime and cement resources by Buehler in 1907, and that on iron ores by G. W. Crane in 1912.

In addition to the publications of the State surveys, there were a large number of short articles published. The United States Geological Survey, however, issued a few important reports: (1) a bulletin on the flora of the outlying Carboniferous basins of southwestern Missouri and a very complete monograph on the flora of the lower coal measures, chiefly of Henry County, by David White, (2) a generalized description of the western interior coal field by H. F. Bain in 1902, (3) an account of the underground waters of the State and their geological relations by E. M. Shepard in 1907, (4) a description of pockets and outliers in the Joplin area by Smith and Siebenthal, and (5) the geology of the St. Louis quadrangle by N. M. Fenneman. The State and Federal Surveys co-operated to publish in 1912 an economic report on coal by one of the present writers.

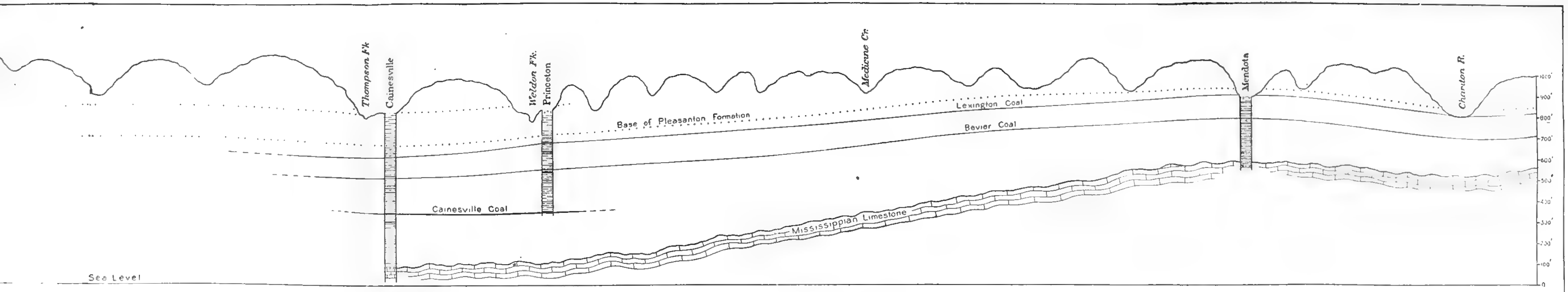
Although, as shown above, there is a fair amount of published material on the Pennsylvanian rocks of Missouri, it was not until the inauguration of the recent co-operative work in 1910 that an attempt was made to trace formational outcrops from the Kansas to the Iowa boundaries, and to bring together and correlate in coherent form the results of all earlier work and of the many excellent drill records recently obtained. During the last two decades, the reports of the Kansas and Iowa Surveys have thrown considerable light on Missouri problems.

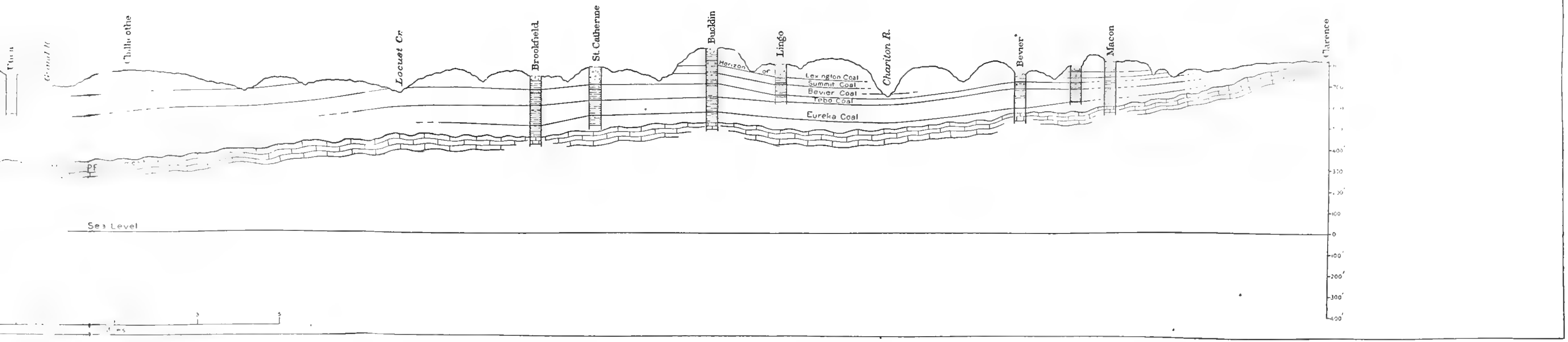


CROSS-SECTIONS FROM LEAVENWORTH TO BRUNSWICK AND FROM CONNELSVILLE TO COLUMBIA.



CROSS-SECTIONS FROM WEST TO EAST IN NORTH MISSOURI.





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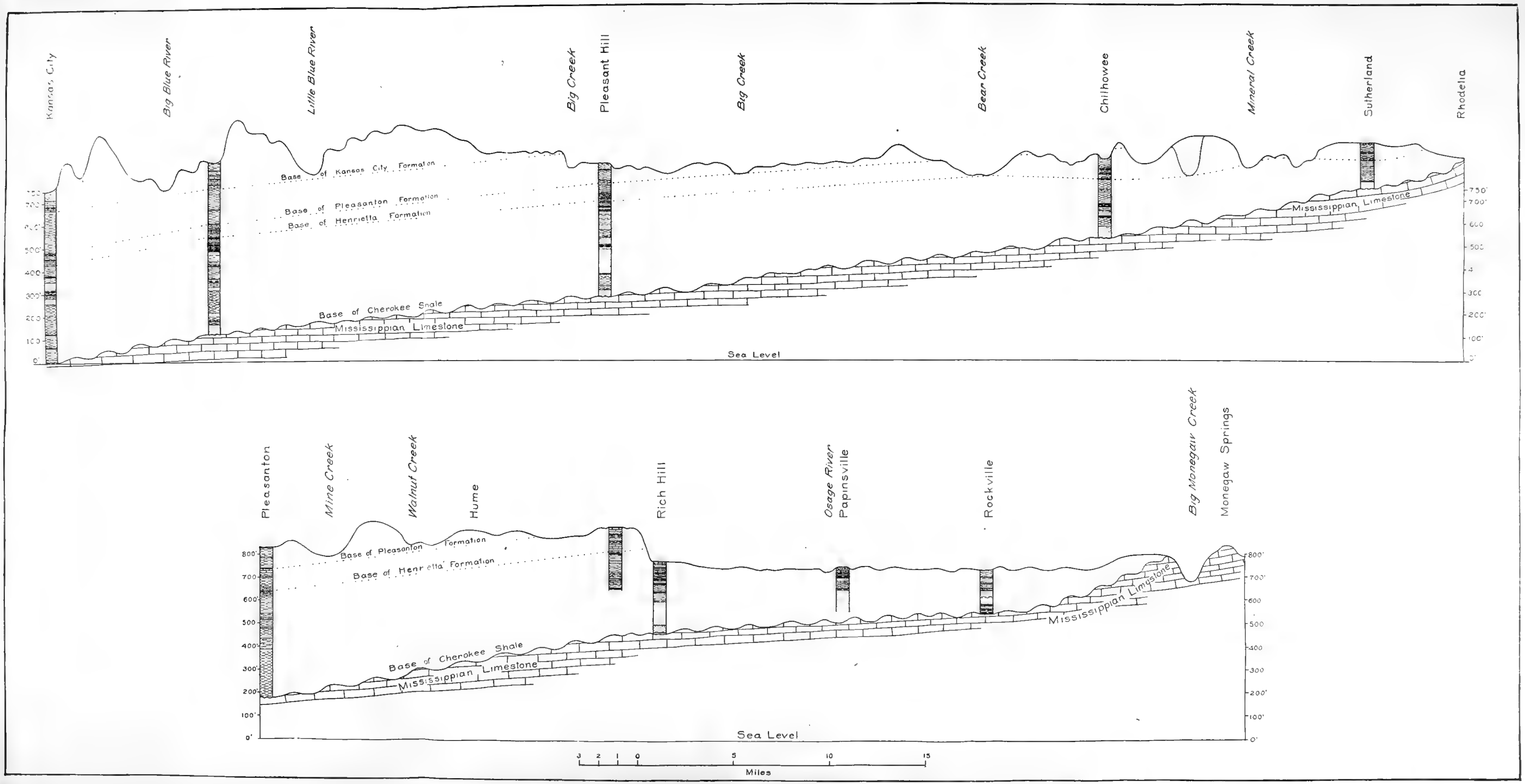

CROSS-SECTION FROM KANSAS CITY TO NEAR WINDSOR AND FROM PLEASANTON, KAN., TO MONEGAW SPRINGS, MO.

NOMENCLATURE.

VARIOUS SYSTEMS OF GROUPING.

Many geologists who have investigated the Pennsylvanian rocks of the western interior coal region have attempted to group the beds in series, groups, stages, formations, and members, often using these terms as though they were essentially of the same rank. There are two problems involved in differentiating the beds, one, that of determining the stratigraphic boundaries and rank of the units, and, the other, that of applying proper geographic names.

In 1855 Swallow segregated three divisions of the Pennsylvanian, then known as the "Coal Measures" or "Upper Carboniferous," and termed them "Upper, Middle, and Lower Coal Series." It is to be regretted that his divisions cannot be correlated definitely with the units which have been segregated more recently.

When Broadhead[1] published his first Missouri River section, he said, "For convenience and comparison, I have separated the coal series into several groups, each possessing characters somewhat peculiar, and separable from each other by moderately well marked natural lines, but there can scarcely be said to be any strongly marked groups." The groups are apparently attempts to combine topographic, lithologic, and faunal criteria.

BROADHEAD'S FIRST GROUPING AND MODERN EQUIVALENTS.

Group.	Nos. (1868.)	Thickness. *Feet.*	Modern equivalents.
A	1– 47	370	Top of section to Severy shale member, inclusive.
B	48– 69	76	Topeka limestone and Calhoun shale members.
C	70– 98	178	Deer Creek limestone member to Kanwaka shale member, inclusive.
D	99–133	337	Oread limestone member to Vilas shale member, inclusive.
E	134–146	134	Plattsburg limestone member to Chanute shale member, inclusive.

[1] Broadhead, G. C., Coal Measures in Missouri: St. Louis Acad. Sci. Trans., vol. 2, pp. 311-333, 1868 (first issued July 27, 1865).

BROADHEAD'S FIRST GROUPING AND MODERN EQUIVALENTS —Continued.

Group.	Nos. (1868.)	Thickness. *Feet.*	Modern equivalents.
F	147–172	174	Drum limestone member to 28 feet below top of Pleasanton formation.
G	173–193	176	Remainder of Pleasanton formation to Fort Scott limestone member, inclusive.
H	194–284	588	Cherokee shale.
I	....	60–90	Cherokee shale.

When the stratigraphy along the Missouri Pacific Railroad in Pettis, Johnson, Cass and Jackson counties was studied, Broadhead made further subdivisions, mainly in the Des Moines group. These, he also termed "groups," and named, from the base upward: (1) "Clear Fork," (2) "Knob Noster," (3) "Warrensburg," (4) "Lexington," (5) "Holden," (6) "Mound." Number 7, the remaining division, was called the "Upper Coal Measures." The "Clear Fork," "Knob Noster," and "Warrensburg" are the Cherokee shale of the present classification; the "Lexington" corresponds approximately with the Henrietta; and the "Holden" and "Mound" with the Pleasanton formation and the Hertha and Ladore members of the Kansas City formation.

In the same report the "Lower," "Middle" and "Upper Coal Measures" of Swallow were first adequately defined: the lower division including approximately the strata from the base of the Cherokee to the underclay of the Mulky coal seam; the middle division, the remainder of the Cherokee, and the Henrietta and Pleasanton; and the upper division the Missouri group. The "Upper Coal Measures" included 16 feet of strata (Broadhead's numbers 72 and 73) that are now referred to the Pleasanton. Later, however, the "Lower" and "Middle" were thrown together into the "Lower Coal Measures."

Winslow in 1891 used the terms "Lower," "Middle," and "Upper Coal Measures" and the two lower divisions were mapped in the Higginsville and Bevier quadrangles.

The names Missouri and Des Moines were introduced by Keyes in 1892, when he proposed Missouri "stage" to correspond "essentially with the 'upper' Coal Measures, representing the more strictly marine beds," and Des Moines "stage" to correspond with "the lower Coal Measures, or the marginal deposits of the upper Carboniferous." In 1894 he stated that "the great limestone of Winterset may be regarded as the base of the 'upper' Coal Measures" and that "in Missouri, it appears to be continued in what is known as the Bethany Falls limestone." The basal member of the "great limestone at Winterset" has recently been found to be Broadhead's number 74 (Hertha). Broadhead republished his sections in 1895 and definitely drew the base of the "Upper Coal Measures" at his number 74, a procedure that was afterward followed by the Missouri Survey. In this report, therefore, the Hertha is considered to be the base of the Missouri group.

In the same report Broadhead correlated his groups of 1868 with his numbered section of 1872.

BROADHEAD'S LAST GROUPING OF THE PENNSYLVANIAN.

Group.	Numbers.	Thickness. *Feet.*
A	Top to 212	310
B	212 to 188	43
C	188 to 150	200
D	150 to 108	400
E	108 to 96	154
F	96 to 72	154
G	72 to Lexington coal	175
H	Lexington coal to base	588

The classification used in this report is that of the Kansas University Geological Survey modified by the results of recent field and office work in Missouri. The present and other classifications are shown in the long table at the end of this chapter.

NAMES AND THEIR PROPER APPLICATION.

GENERAL STATEMENT.

There has been much confusion in the naming of members and formations in the western interior coal field. Owing to the fact that some of the first names were published in reports not easily obtainable for reference, some of them were afterward overlooked; in other cases, the names applied were already in use elsewhere for some other formation. The classification adopted in this report is believed to be applicable to Iowa, Missouri, and Kansas, and in part to Oklahoma. It has been carefully considered and approved by the Committee on Geologic Names of the U. S. Geological Survey.

Swallow, Broadhead, and other early workers in this field used very few names, designating beds by numbers that referred them to various general sections. Later investigators in Iowa and Missouri have also avoided as much as possible minute subdivision and naming of members. Many names have been introduced in Kansas, however, and in this report the classification recently published by the Kansas University Geological Survey in volume 9 of its reports has been adhered to as closely as possible. There have been introduced a few Missouri and Iowa names that were in use before their Kansas equivalents were adopted, and two of the major formations of the Kansas Survey have been divided on both faunal and lithologic grounds, and their constituent parts renamed or assigned names already in common usage in Missouri. The Shawnee formation remains unchanged, though it is recognized that it transgresses a faunal stage. With the exception of two formation names and four names for minor limestone beds all the names employed have already been proposed by other writers.

DES MOINES GROUP.

The name Des Moines[1] was proposed by Keyes in 1893 to represent the "lower Coal Measures" or the "marginal deposits of the upper Carboniferous." The term was soon more exactly defined and has since been in general use in Missouri and Iowa. In 1896, Keyes[2] himself says, "over the whole of its areal extent in the western interior coal field the Des Moines series, or productive coal measures, is clearly limited above by the Bethany limestone and below by the Mississippian or earlier formations." The term Bethany, as employed by Keyes, included the Bethany Falls limestone of Broadhead and the beds just above and below it.

CHEROKEE SHALE.

DEFINITION.

The name Cherokee[3] was first given to this formation, the lowest of the Des Moines group, by Haworth and Kirk.

[1] Keyes, C. R., The geological formations of Iowa: Iowa Geol. Survey, vol. 1, pp. 85-114, 1893.

[2] Keyes, C. R., Stages of the Des Moines, etc.: Iowa Acad. Sci. Proc., vol. 4, pp. 22-25, 1896.

[3] Haworth, E., and Kirk, M. Z., The Neosho River section: Kansas Univ. Quart., vol. 2, p. 105, 1894.

Since then practically every publication dealing with the formation has used the name, which has become firmly established in the literature of Kansas and Missouri, and it has therefore been adopted by the United States Geological Survey, the previous application of the term Cherokee to rocks in North Carolina and to a Mississippian limestone in the Ozark region being considered as obsolete.

A number of names of more or less local significance have been applied to members of the Cherokee shale. These are referred to only incidentally in this report, as it is believed that it is much simpler and just as adequate to designate beds by indicating their relation to the persistent coal beds in the upper part of the formation.

The name Graydon Springs sandstone and conglomerate[1] was first suggested by W. P. Jenney and afterward used by Winslow, to apply to Pennsylvanian deposits in Lawrence, Greene, and Dade counties that occupy depressions in Mississippian rocks. The name was shortened to Graydon sandstone[2] by Shepard and was extended by him[3] and by other writers to coarse deposits filling channels and depressions in the pre-Pennsylvanian land surface from Callaway County to southwest Missouri. The lithologic and apparently stratigraphic similarity of the various sandstones and conglomerates termed Graydon appears to be due more to the similarity of the somewhat unique conditions under which they were formed than to strict identity in age. The same may be said of the Saline Creek cave conglomerate[4] of Ball and Smith, a deposit recognized as filling solution cavities in the pre-Pennsylvanian rocks of Morgan and Moniteau counties.

In Kansas the term "Columbus sandstone"[5] has been used for arenaceous sediments about 150 feet above the base of the Cherokee shale, but "Columbus" is preoccupied as a formation name, by application to a Devonian limestone in Ohio.

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[1]Winslow, Arthur, Lead and zinc deposits: Missouri Geol. Survey, vol. 7, pp. 422-425, 1894.

[2]Shepard, E. M., Geology of Greene County: Missouri Geol. Survey, vol. 12, p. 124, 1898.

[3]Shepard, E. M., Underground waters of Missouri: U. S. Geol. Survey Water-Supply Paper 195, p. 22, 1907.

[4]Ball, S. H., and Smith, A. F., Geology of Miller County: Missouri Bureau of Geology and Mines, vol. 1, 2nd series, p. 92, 1903.

[5]Haworth, E., and Kirk, M. Z., The Neosho River section: Kansas Univ. Quart., vol. 2, p. 106, 1894.

Broadhead gave the name "Clear Creek sandstone"[1] to about 50 feet of sandstone in the upper part of the lower division of the Cherokee shale in Barton and the neighboring counties, but this name is preoccupied by Worthen's use of Clear Creek limestone[2] for a Devonian formation in Illinois, and further complications have ensued from the application of the name "Clear Creek" by Keyes and by Wheeler to Silurian limestones in Missouri and by Drake to Carboniferous beds in Texas.

The name Cheltenham[3] applied to the fire clay of the St. Louis district, is also applicable, according to David White, to the basal clays utilized in Audrain, Callaway and Boone counties.

Aside from the coal beds, the only single layer in the lower part of the Cherokee to which a name has been given is the nodular limestone lying a few feet below the Bevier coal bed. This limestone, termed the Ardmore limestone by Gordon,[4] is the hydraulic limestone of Swallow.

In the upper part of the Cherokee the arenaceous deposits immediately above the Bevier coal have been given the name Lagonda sandstones and shales[5] by Gordon. It is probable that he intended to include under this designation the material between the Bevier coal bed and the underclay of the Mulky (Macon City) coal bed. Where the Mulky and its closely associated cap-rock are absent, however, it is not practicable to distinguish these rocks fron the remainder of the Cherokee.

In an economic report on the clays and shales of the Bevier quadrangle, Wheeler[6] applied to several beds in both the lower and upper parts of the Cherokee names that have not, however, come into general use. The underclay of the Bevier coal he called the Bevier fire-clay, that of the Tebo (Lower Ardmore) coal the Miller fire-clay, and that of the Summit coal the Thomas Hill fire clay. The shale bed above the cap-rock of the Mulky (Macon City) coal he designated as the Macon City shale,

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[1]Broadhead, G. C., The Geology of Barton County: Missouri Geol. Survey, Rept. 1873-74, p. 100, 1874.

[2]Worthen, A. H., Devonian and Silurian systems: Illinois Geol. Survey, vol. 1, pp. 126-129, 1866.

[3]Wheeler, H. A., The clay deposits of Missouri: Missouri Geol. Survey, vol. 11, p. 246, 1896.

[4]Gordon, C. H., A report on the Bevier sheet: Missouri Geol. Survey, Sheet Rept. No. 2, p. 20, 1893.

[5]Idem p. 19.

[6]Wheeler, H. A., Clays and shales (of the Bevier sheet): Missouri Geol. Survey, Sheet Rept. No. 2, pp. 57-65, 1893.

and that a few feet above the Lower Ardmore coal bed as the Pottery shale.

Non-geographic descriptive names have been occasionally used in Missouri and neighboring parts of Kansas for various members. The term "diamond rock" was assigned to a thin limestone in the Fort Scott region that is probably to be correlated with a similar bed in Vernon and adjacent counties and with the limestone cap-rock of the Mulky coal bed. Swallow's terms "Fort Scott marble" and "Fort Scott series" were also used for the Mulky cap-rock and rocks closely associated with it. In the northern half of the Cherokee shale outcrop Broadhead called the cap-rock of the Summit coal bed the "Rhomboidal limestone" and the limestone just below the horizon of the Lexington coal bed the "Chaetetes limestone." It was Broadhead's usual custom to refer to different beds by numbers that corresponded with those in one of his general sections of the State or of one or more counties.

HENRIETTA FORMATION.

DEFINITION.

The name Henrietta, from a postoffice (now abandoned) in Johnson County, Mo., was first used by Marbut in a physiographic sense in 1896, and first given stratigraphic definition by Keyes,[1] who included in it the Pawnee limestone, Labette ("Marmaton") shale, and Fort Scott limestone. As mapped by Marbut in the Clinton, Calhoun, Lexington, and Richmond sheets the Henrietta[2] included beds in the upper part of the Cherokee, but he definitely stated that it was intended to include the Fort Scott limestone at the base and the Pawnee limestone at the top. Prior to Keyes' paper Bain applied the name "Appanoose"[3] to an approximately equivalent terrane in Appanoose County, Iowa, which, however, is believed to include part of the Pleasanton at the top and part of the Cherokee at the base. In 1898 Bain and Leonard suggested that both the names Henrietta and Appanoose[4] be reserved for local use and a new

[1]Keyes, C. R., Stages of the Des Moines, etc.: Iowa Acad. Sci Proc., vol. 4, pp. 22-24, 1896.

[2]Marbut, C. F., Geological descriptions of the Clinton, Calhoun, Lexington and Richmond sheets: Missouri Geol. Survey, vol. 12, Pt. 2, 1898.

[3]Bain, H. F., Geology of Appanoose County: Iowa Geol. Survey, vol. 5, pp. 374-409, 1896.

[4]Bain, H. F., and Leonard, A. G., The Middle Coal Measures of the Western Interior field: Jour. Geology, vol. 6, pp. 577-588, 1898.

general term be adopted for the Western Interior region. They recognized, however, that "Appanoose," being coextensive with a coal bed, is more local than Henrietta, and as the latter term has been in general use in Missouri for some time it is adopted in this report. Another potent objection to the use of the term "Appanoose" is that it was originally defined to include a coal bed (Mystic-Lexington) now thought to lie near the top of the Cherokee shale, as originally defined.

Haworth later combined all beds between the Cherokee shale and the top of the "Lower Coal Measures" (Des Moines group) in the "Marmaton formation."[1] Keyes had previously used the name Marmaton for the shale in the middle of the Henrietta (the Labette shale member of this report). While a grouping under one name of all the beds of the Des Moines group above the Cherokee shale may be useful in Kansas, it is hardly applicable to Missouri, where the Henrietta and the overlying Pleasanton formation are sharply distinguished lithologically.

MEMBERS OF THE HENRIETTA FORMATION.

Fort Scott limestone member.—Swallow applied the name "Fort Scott coal series"[2] to a series of strata which included a bed called by him the Fort Scott limestone (upper bed of the Fort Scott limestone member as here recognized), and the name "Fort Scott marble series" to a succession of strata which included a bed called by him the Fort Scott marble. In a geologic section through Fort Scott, Kans., to Nevada, Mo., by Hay, the name Fort Scott limestone[3] was used for the upper bed and "Fort Scott cement limestone" was used for the impure limestone next below it. Later Haworth and Kirk used "Oswego"[4] for both the upper and lower limestones and the included shale, but, as Prosser[5] had the year before applied that name to a Silurian formation in New York, the Kansas Survey later abandoned "Oswego" and substituted for it the old name

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[1]Haworth, E., Stratigraphy of the Kansas Coal Measures: Kansas Univ. Geol. Survey, vol. 3, p. 92, 1898.

[2]Swallow, G. C., Preliminary report of Geological Survey of Kansas: pp. 25-26, 1866.

[3]Hay, Robert, Natural gas in eastern Kansas: Kansas State Board Agric., Fifth Bienn. Rept., p. 204, 1887.

[4]Haworth, E., and Kirk, M. Z., The Neosho River section: Kansas Univ. Quart., vol. 2, pp. 105, 106, 107, 116, 1894.

[5]Prosser, C. S., The thickness of the Devonian and Silurian rocks of central New York: Geol. Soc. America Bull., vol. 4, pp. 100, 108, 116, 1893.

Fort Scott limestone.[1] The name as now used by the Kansas Survey and adopted in this report includes, therefore, the bed originally called Fort Scott limestone by Swallow, the next lower limestone ("cement rock"), and the thin interval of shale, coal, and clay between them.

Labette shale member.[2]—This member was named by Haworth in 1898 and the name has been in general use since. As shown above, Keyes in 1897 used the term "Marmaton" for this member. The name "Marmaton," therefore, has priority over Labette, but the subsequent use of "Marmaton" in a wider sense has led to the abandonment of that name and the adoption of Labette, which has been consistently applied in the literature to this member. The Labette and Pawnee members and the overlying Pleasanton formation were all included in the term "Laneville shales."[3]

Pawnee limestone member.—Swallow first used this name in 1866[4], applying the name "Pawnee limestone series" to a group of beds which included not only this member (called by Swallow, Pawnee limestone), but underlying beds as well. Swallow's broad usage of the name did not gain currency and is long since obsolete, but the name has become firmly established in the literature in the restricted sense in which he used it and in which it is here employed.

PLEASANTON FORMATION.

DEFINITION.

Some confusion has arisen in the use of the name Pleasanton. As first introduced in 1895 the term Pleasanton[5] was applied to all beds lying between the Pawnee limestone and the base of the Missouri group. These beds formed the upper part of the "Middle Coal Measures" of early geologists, of the Des Moines "stage" of Keyes, and of the "Marmaton formation" of Haworth. They were included in the "Marais des Cygnes coal series" of Swallow's section, and are equivalent to the

[1]Haworth, E., and Bennett, John, General stratigraphy: Kansas Univ. Geol. Survey, vol. 9, pp. 81-82, 1908.

[2]Haworth, E., Stratigraphy of the Kansas Coal Measures: Kansas Univ. Geol. Survey, vol. 3, pp. 36-37, 92, 94, 100, 1898.

[3]Haworth, E., and Kirk, M. Z., The Neosho River section: Kansas Univ. Quart., vol. 2, pp. 104-112, 1894.

[4]Swallow, G. C., Preliminary report of Geological Survey of Kansas: pp. 9-28, 1866.

[5]Haworth, E., The stratigraphy of the Kansas Coal Measures: Kansas Univ. Quart., vol. 3, p. 274, 1895.

"Marais des Cygnes shales"[1] of Keyes. In 1894 Haworth and Kirk used the name "Laneville shales"[2] to include the beds here called Pleasanton formation as well as the underlying Pawnee limestone and Labette shale, but the name "Laneville" was soon abandoned. In 1895 Hawarth divided the Pleasanton into an upper and a lower division, separated in part of the State by the Altamont limestone. In 1908, having found both the Altamont and the Coffeyville limestones of the Kansas Survey to be persistent, he restricted the name Pleasanton to the shales above the "Coffeyville" limestone, gave a new name to the shales below the "Coffeyville" limestone, and accepted Adams' name Bandera for the shales between the Altamont and the Pawnee. Soon after the original definition of the Pleasanton in 1895, however, the name was adopted for all Des Moines strata above the Henrietta formation in Missouri and above the "Appanoose beds" in Iowa, and has been in constant use in those states since that time. This usage corresponds with the original definition of Pleasanton, since the upper member of the Henrietta is the Pawnee limestone, and is the definition adopted in this report.

The variable and lenticular character of Pleasanton sediments in Missouri and the absence of adequate stratigraphic markers makes it inadvisable to segragate any portion of them as members in the greater part of the State. Future detailed mapping, especially near the Kansas boundary, may, however, show the practicability of local differentiation.

MISSOURI GROUP.

Keyes proposed the name Missouri "stage"[3] to correspond essentially with the non-geographic term "Upper Coal Measures" and to include the beds typically developed in northwestern Missouri. Since that time its lower boundary has been more explicitly defined in many publications and the name has been in general use in Missouri and Iowa. In 1896 Keyes proposed that the term "Missourian" be used, and that it be considered co-ordinate with Mississippian series. The latter suggestion has

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[1] Keyes, C. R., Formational synonymy of the coal measures of the Western basin: Iowa Acad. Sci. Proc., vol. 7, p. 84, 1900.

[2] Haworth, E., and Kirk, M. Z., The Neosho River section: Kansas Univ. Quart., vol. 2, pp. 104-115, 1894.

[3] Keyes, C. R., The geological formations of Iowa: Iowa Geol. Survey, vol. 1, pp. 85-114, 1893.

never been seriously considered, however, and the term Missouri group is here employed in order to conform with recognized usage in distinguishing the major divisions of a series.

KANSAS CITY FORMATION.

DEFINITION.

The name Kansas City has been mentioned in other connections. In 1886 Broadhead[1], in describing a limestone in Miami and Franklin counties, Kans., says it "very much resembles the Kansas City oölite, but is probably a different stratum higher in the series." Gallaher,[2] in 1898, applied the name Kansas City limestone to at least three limestones, through a series of miscorrelations. It is not believed, however, that these two instances, one a mere mention and the other an extremely indefinite application, can cause any confusion of the term Kansas City formation as here used. The name is derived from Kansas City, Mo., where the formation is typically exposed. It is subdivided into the members listed in the table on page 7, and described below.

MEMBERS OF THE KANSAS CITY FORMATION.

Hertha limestone member. — Considerable confusion has existed in previous correlations of the five lower members of the Kansas City formation. Three limestones with separating shales have long been recognized at the base of the Missouri group in Kansas, Missouri and Iowa. In southeastern Kansas they were best known, perhaps, as the Bethany Falls or Hertha, the Mound Valley, and the Dennis limestones. In Missouri only the middle one, the Bethany Falls, has received a name. In Iowa, the names Fragmental, Earlham, and Winterset were applied. The Kansas Geological Survey made the correlation in the western part of Kansas City, where the Hertha is below drainage and the Bethany Falls and Winterset outcrop, the latter member containing a shale parting. The Iowa Survey carried its investigations south to Bethany, where a similar condition prevails, the Hertha being below drainage and the thick Winterset limestone at that time seemingly exposed as two beds.

Mr. Greene's conception of the equivalence of the terms

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[1]Broadhead, G. C., Carboniferous rocks of eastern Kansas: St. Louis Acad. Sci. Trans., vol. 4, p. 483, 1886.

[2]Gallaher, J. A., Bienn. Rept. State Geologist: Missouri Bureau of Geology and Mines, p. 51 et seq., 1898.

used in the present and former publications is shown in the following table:

CORRELATION OF THE FIVE LOWER MEMBERS OF THE KANSAS CITY FORMATION.

Kansas Survey[a] (southeastern Kansas).	Kansas Survey (Kansas City, Mo.)	U. S., Missouri, and Iowa Geol. Surveys (names recently adopted.)	Iowa Survey[b] (Bethany, Mo.)	Iowa Survey (in general).
Dennis limestone	Dennis limestone Galesburg shale Mound Valley limestone	Winterset limestone	Limestone Unexposed Limestone	Winterset limestone
Galesburg shale	Ladore shale	Galesburg shale	6- to 8-foot interval	Unnamed shale
Mound Valley limestone	Bethany Falls limestone	Bethany Falls limestone	Bethany Falls limestone (Fragmental)	Earlham limestone
Ladore shale	Not mentioned	Ladore shale	Not exposed.	Unnamed shale
Bethany Falls limestone	Not mentioned	Hertha limestone	Not exposed	Fragmental limestone

[a] Since the publication of volume 9 of the Kansas Survey Reports, Dr. Haworth has written to David White, Chief Geologist of the U. S. Geol. Survey, that recent field work has demonstrated the equivalence of the "Bethany Falls," "Mound Valley," and "Dennis" limestones of southeastern Kansas with the Hertha, Bethany Falls, and Winterset, respectively, as here defined, and has adopted the above nomenclature, except that Dennis is used instead of Winterset.

[b] The Iowa Survey, as explained on page 25, has reconsidered the section at Bethany, and as a result will use the names here adopted.

Adams proposed the name Hertha,[1] derived from Hertha, Kans., for the lowest of the three limestones which mark the base of the Missouri group. The three limestones collectively were formerly known in Kansas as the "Erie, or Triple system," and as the "Bronson limestone." In 1898 Haworth[2] supposed the

[1] Adams, G. I., Stratigraphy and paleontology of the Upper Carboniferous rocks of the Kansas section: U. S. Geol. Survey Bull. 211, p 35, 1903.

[2] Haworth, E., Stratigraphy of the Kansas Coal Measures: Kansas Univ. Geol Survey, vol. 3, pp. 45-46, 1898.

Hertha limestone in southeastern Kansas to be the equivalent of the Bethany Falls, and so termed it. Later work, however, has shown the Hertha to be the limestone below the true Bethany Falls limestone (Broadhead's number 74), and accordingly the name Hertha becomes applicable to the lowest member of the Missouri group in Kansas. The so-called Bethany Falls limestone or Hertha of southeastern Kansas has been traced by Bennett to "Rock Mound" near Hume, Mo. (sec. 5, T. 38 N., R. 33 W.), where Broadhead identified it with his number 74. Concerning this, Broadhead[1] says "The farthest point south where limestones of this horizon ("Upper Coal Measures") have been recognized was in the top of a mound (Tp. 38 N., R. XXXIII W., Sec. 5). This rock may be referred to number 74 of the general section."

In Iowa a somewhat similar correlation was made by Bain.[2] Three limestones at the base of the Missouri group were noted and the lowest, the "Fragmental," was correlated with the Bethany Falls. Field work by Prof. J. L. Tilton, of the Iowa Geological Survey, and Mr. Greene in 1912, however, showed the "Fragmental" limestone to be the Hertha, instead of the Bethany Falls limestone. This correlation has been adopted by the Iowa survey.[3]

Ladore shale member.—The name Ladore[4], from Ladore, Kans., was first used by Adams to designate the shale between the Hertha and "Mound Valley" limestones. As has been shown, the latter is the true Bethany Falls limestone and, accordingly, the name Ladore is here used for the shale between the Hertha and Bethany Falls limestones. Its correlation has already been discussed. This member was originally named the "Mound Valley shale," but as "Mound Valley" was at the same time applied to the limestone above, and has long since been replaced by Ladore for the shale, the adoption of the latter well-established name is believed to be preferable to the revival of the original name "Mound Valley."

Bethany Falls limestone member.[5]—Broadhead first used

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[1]Broadhead, G. C., The Coal Measures of Missouri: Missouri Geol. Survey, vol. 8, p. 371, 1895.

[2]Bain, H. F., Geology of Decatur County: Iowa Geol. Survey, vol. 8, pp. 258-309, 1898.

[3]Tilton, J. L., The proper use of the geological name, "Bethany": Iowa Acad. Sci. Proc., vol. 20, pp. 207-211, 1914.

[4]Adams, G. I., Economic geology of the Iola quadrangle, Kansas: U. S. Geol. Survey Bull. 238, Pl. 1, 1904.

[5]Broadhead, G. C., Coal Measures in Missouri: St. Louis Acad. Sci. Trans., vol. 2, p. 320, 1868 (read May 5, 1862, first issued July 27, 1865).

this name in 1862 for the limestone forming the falls of Big Creek at Bethany, Mo. It has been in use in the publications of the Missouri Geological Survey since that time, but the name was neglected in Kansas and Iowa for many years. It corresponds to the "Mound Valley" limestone of southeastern Kansas and the "Earlham" limestone of Iowa. The shortened term Bethany has been used rather extensively by Iowa geologists to include a number of associated beds of limestone at the base of the Missouri group, a misuse of Broadhead's original name. The name is here adopted with its original significance.

Galesburg shale member.[1]—This member was named by Adams from Galesburg, Kans. Its correlation has already been discussed. No other name is known to have been applied to this member.

Winterset limestone member.—The name Winterset[2] was given by Tilton and Bain to a limestone at Winterset, Iowa, which corresponds to that above the Bethany Falls limestone in Missouri and with the "Dennis" in southeastern Kansas. It has been stated by Keyes[3] that the term Winterset was used by White to refer to a group of limestone beds. White frequently used the expression "No. —— of the Winterset section," but it is not believed that he intended to use Winterset as a geologic name.

Subsequent to the application of the name of Winterset, the name "Dennis"[4] was proposed by Adams for this limestone from outcrops at Dennis, Kans., but the use of Winterset antedates that of "Dennis," and the former term is here adopted.

Cherryvale shale member.[5]—The shale next above the Winterset limestone was named from Cherryvale, Kans. So far as known, no other name has ever been applied to this member.

Drum limestone member.[6]—This name was first used by Adams. It was taken from Drum Creek, Kans., applying to a single limestone at that place. It was introduced to replace the name "Independence," which was preoccupied by a De-

[1]Adams, G. I., Stratigraphy and paleontology of the Upper Carboniferous rocks of eastern Kansas: U. S. Geol. Survey Bull. 211, p. 18, 1903.

[2]Tilton, J. L., and Bain, H. F., Geology of Madison County: Iowa Geol. Survey, vol. 7, pp. 517-519, 1897.

[3]Keyes, C. R., The Bethany limestone of the Western Interior Coal field: Am. Jour. Sci., 4th ser., vol. 2, pp. 224-225, 1896.

[4]Adams, G. I., Stratigraphy and paleontology of the Upper Carboniferous rocks of eastern Kansas: U. S. Geol. Survey Bull. 211, p. 36, 1903.

[5]Haworth, E., Stratigraphy of the Kansas Coal Measures: Kansas Univ. Geol. Survey, vol. 3, p. 483, 1896.

[6]Adams, G. I., op. cit., p. 37.

vonian shale in Iowa. Schrader later used the name Drum[1] for a formation consisting of one to three or more members.

According to the present correlation there are between the Winterset ("Dennis") and Iola limestones, in southeastern Kansas, the Cherryvale shale, Drum limestone, and Chanute shale members. Little or no doubt has been expressed as to the correlation of the two shale members, but there is some question as to what part of the section at Kansas City is equivalent to the Drum limestone. To quote from Haworth and Bennett,[2] it "probably is the equivalent of one of the limestones in the bluffs at Kansas City. Doctor Beede says that 'faunally it agrees with the Oölite of Kansas City.'" For this reason Broadhead's numbers 87a-b are herein correlated with the Drum, and the two next higher limestones, his numbers 90 and 96, are classed as beds in the Chanute shale member, though the whole section, numbers 87 to 96, inclusive, may prove to be the Drum of southeastern Kansas.

The DeKalb ("Fusulina") limestone of the Iowa Survey, which is the first limestone above the Winterset, may possibly prove to be the same as the Drum, as it agrees faunally and lithologically with that member in northern Missouri.

Chanute shale member.—The name Chanute[3] was given to this shale from exposures near Chanute, Kans. In volume 9 of the Kansas Survey reports the Chanute shale is correlated in one place with the beds between Broadhead's numbers 87a and 98 at Kansas City, but in another place a tentative correlation with Broadhead's number 97 is made and the thickness of the Chanute shale at Kansas City is given as 25 feet, which is the thickness of Broadhead's number 97 alone.

For the reasons stated under the description of the Drum limestone, there is some doubt as to the lower limits of the Chanute, but for the present it is made to include all the beds of shale and limestone between Broadhead's numbers 88 and 97, inclusive. Two thin but fairly persistent beds of limestone in the Chanute shale are here named the Cement City limestone bed and the Raytown limestone bed, the names being taken from localities in Jackson County, Mo. The lower, the Cement City, is possibly the same as the Westerville limestone of Iowa, but

[1]Schrader, F. C., U. S. Geol. Survey Geol. Atlas, Independence folio (No. 159), p. 2, 1905.

[2]Haworth, E., and Bennett, John, General stratigraphy: Kansas Univ. Geol. Survey, vol. 9, p. 96, 1908.

[3]Haworth, E., and Kirk, M. Z., The Neosho River section: Kansas Univ. Quart., vol. 2, p. 109, 1894.

the correlation cannot be definitely made. It is believed to be the Parkville limestone of Gallaher. There is also a possibility that the upper or Raytown bed may be the equivalent of the "Earlton limestone"[1] of Adams. For the Chanute shale as a whole the name "Thayer" has also been used, but Chanute has priority over "Thayer" and is therefore herein adopted.

Iola limestone member.—The Iola[2] was named from exposures at Iola, Kans. It has been correlated by the Kansas Survey with Broadhead's number 98 at Kansas City, where it is one of the most prominent beds. No other name is known to have been applied to this member except through miscorrelation. It is the uppermost member of the Kansas City formation.

LANSING FORMATION.

DEFINITION.

The name Lansing is derived from Lansing, Kans., in which locality many quarries, shale pits, and natural outcrops present fine exposures of all its members. The rocks comprise the upper part of the Pottawatomie formation of Kansas geologists (the lower part of the Pottawatomie being represented by the Kansas City formation of this report), and collectively form a natural map unit, which is faunally distinct from the underlying Kansas City formation.

MEMBERS OF THE LANSING FORMATION.

Lane shale member.[3]—The bed of shale and sandstone above the Iola limestone, was named from Lane, Kansas. Adams gave the name "Concreto" to this shale, and Keyes used the name "Parkville"[4] for it, but the name Lane has priority over both of these names. Near the middle of the member is an arenaceous and ferruginous limestone (Broadhead's number 100) varying from less than one foot to ten feet in thickness. This limestone is believed to be the equivalent of the limestone 40 feet above the Iola limestone in Kansas to which the name "Carlyle limestone" has been applied, but the Kansas Survey has correlated the limestone at Carlyle with the overlying

[1]Adams, G. I., Physiography of southeastern Kansas: Kansas Univ. Quart., vol. 7, p. 96, 1898.

[2]Haworth, E., and Kirk, M. Z., The Neosho River section: Kansas Univ. Quart., vol. 2, p. 109, 1894.

[3]Haworth, E., The stratigraphy of the Kansas Coal Measures: Kansas Univ. Quart., vol. 3, p. 277, 1895.

[4]Keyes, C. R., The Missourian series of the Carboniferous: Am. Geologist, vol. 23, p. 305, 1899.

Plattsburg ("Allen") limestone, and for this reason Broadhead's number 100 should probably be considered a bed in the Lane shale. It is here proposed to name Broadhead's number 100 the Farley limestone bed from exposures near Farley, Platte County, Mo.

Plattsburg limestone member.—The name Plattsburg[1] was given to this limestone by Broadhead in 1862, from the place of that name in Clinton County, Mo. The Plattsburg is the lower of two closely associated beds of limestone. In 1865 Swallow[2] described two beds of limestone in Miami County, Kans., the upper of which has since been correlated with the upper bed of the "Garnett" limestone of the Kansas Survey. He gave the name "Cave rock" to the lower and Stanton to the upper. Broadhead's name Plattsburg has priority over any other geographic name given the lower bed, and Stanton must be used for the upper limestone if the rules of priority are to be observed.

Bennett[3] correlates the Plattsburg (Broadhead's number 108) and Broadhead's number 112, as exposed near Leavenworth, Kans., directly with the lower and upper beds of the "Garnett" limestone. Haworth also states that the "Garnett" limestone extends to Plattsburg, Mo., and beyond. Several other names have been applied to the two limestones, but it is believed that the two here used have priority over any others.

Vilas shale member.—The shale between the Plattsburg and the Stanton limestone was named the Vilas[4] from the town of that name in Kansas. The name has been applied to various beds of shale, but it is used here in the same sense as in folio 159 of the U. S. Geol. Survey and volume 9 of the reports of the Kansas Survey.

Stanton limestone member.—The name Stanton[5] was given by Swallow to this limestone at Stanton, Kans. As before mentioned, Bennett has correlated Broadhead's number 112 with the upper bed of "Garnett" limestone of the Kansas Survey, which

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[1]Broadhead, G. C., Coal Measures in Missouri: St. Louis Acad. Sci. Trans., vol. 2, pp. 317-327, 1868 (read May 5, 1862, first issued July 27, 1865).

[2]Swallow, G. C., Geological report of Miami County, Kansas: Kansas Geol. Survey, p. 71-94, 1866 (also issued separately in 1865).

[3]Bennett, John, A geologic section from Baxter Springs to the Nebraska State line: Kansas Univ. Geol. Survey, vol. 1, p. 71, 1896.

[4]Haworth, E., and Adams, G. I., Stratigraphy of the Kansas Coal Measures: Kansas Univ. Geol. Survey, vol. 3, p. 51, 1898.

[5]Swallow, G. C., Geological report of Miami County, Kansas: Kansas Geol. Survey, p. 75, 1866.

would make it the equivalent of the "Piqua" limestone[1] of Adams.

DOUGLAS FORMATION.

DEFINITION.

The name of this formation was proposed by Haworth[2] in 1898 from exposures in Douglas County, Kans., the second county west of Missouri on the south side of Kansas River. Many fine outcrops of the formation occur in that county and practically the whole formation can be seen on or near Mount Oread at Lawrence, Kans., where the State University is situated.

MEMBERS OF THE DOUGLAS FORMATION.

Weston shale member.[3]—Keyes named this shale from exposures at Weston, Platte County, Mo. It has been included in the "Le Roy" shale and the so-called Lawrence shale (broad sense) in a number of papers. Haworth and Bennett also used the term "Le Roy"[4] for this member, but the name "Le Roy"[5] was originally applied to the entire interval between the Stanton and Oread limestones in a report on reconnaisance work. However, the term Weston, given by Keyes, has priority for the shale between the Stanton and Iatan limestones.

Iatan limestone member.[6]—Like the Weston shale below, this limestone was named by Keyes in 1899, the type locality being at Iatan, Platte County, a few miles above Weston. The name Ottawa has been applied to a limestone in Kansas that may be its equivalent, but this correlation is not yet definitely established, and in any event the name Ottawa is preoccupied in another sense in the geology of Canada. Haworth and Bennett,[7] in 1908, proposed the name "Kickapoo" for this member, taking the name from a village in Kansas just across Missouri River from Iatan, Mo., but that name has no standing in view of the prior use of Iatan for the member.

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[1] Adams, G. I., Economic geology of the Iola quadrangle, Kansas: U. S. Geol. Survey Bull. 238, p. 20, 1904.

[2] Haworth, E., Stratigraphy of the Kansas Coal Measures: Kansas Univ. Geol. Survey, vol. 3, pp. 93, 94, 1898.

[3] Keyes, C. R., The Missourian series of the Carboniferous: Am. Geologist, vol. 23, pp. 298-316, 1899.

[4] Haworth, E., and Bennett, John, General stratigraphy: Kansas Univ. Geol. Survey, vol. 9, p. 105, 1908.

[5] Haworth, E., and Kirk, M. Z., The Neosho River section: Kansas Univ. Quart., vol. 2, p. 110, 1894.

[6] Keyes, C. R., Op. cit.

[7] Haworth, E., and Bennett, John, General stratigraphy: Kansas Univ. Geol. Survey, vol. 9, p. 106, 1908.

Lawrence shale member.[1]—This shale takes its name from Lawrence, Kans. As originally defined, it occupies the interval between the Oread and Ottawa limestones. The latter is considered by Schrader[2] to be next above the Stanton ("Garnett") limestone, a view that appears to make the Ottawa equivalent to the Iatan ("Kickapoo") limestone. The original use of the name Lawrence, therefore, is the same as that used in the present report and in volume 9 of the Kansas Survey. As mentioned under the discussion of the name Weston, the Lawrence-Weston interval was originally included in the "Le Roy" shale, and in several papers published since the original definition of the term Lawrence that name has been extended to cover the entire interval between the Stanton and the Oread. Keyes later used the name "Andrew"[3] for the Lawrence shale. A few other names have been applied to the interval.

The Lawrence shale in places in Missouri and Kansas contains a limestone bed for which the name Amazonia limestone bed is here proposed. This limestone was confused with the Iatan by Broadhead and also by Haworth and Bennett,[4] who thought it was the "Kickapoo" (Iatan) in Doniphan County, Kans.

Oread limestone member.—The Oread limestone[5] was named from outcrops on Mount Oread at Lawrence, Kans. The limestone which outcrops on Missouri River near Plattsmouth, Neb., to which the name "Plattsmouth"[6] was given by Keyes, is believed to be the Oread limestone.

SHAWNEE FORMATION.

DEFINITION.

The name Shawnee,[7] derived from the Kansas county of that name, was first used by Haworth in 1898. As here used, it contains the same members as in the latest revision of Haworth and Bennett[8]; that is, Kanwaka shale to Scranton shale, in-

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[1]Haworth, E., and Kirk, M. Z., The Neosho River section: Kansas Univ. Quart., vol. 2, p. 110, 1894.

[2]Unpublished correlation table.

[3]Keyes, C. R., The Missourian series of the Carboniferous: Am. Geologist, vol. 23, pp. 298-316, 1899.

[4]Haworth, E., and Bennett, John, General stratigraphy: Kansas Univ. Geol. Survey, vol. 9, p. 105, 1908.

[5]Haworth, E., The stratigraphy of the Kansas Coal Measures: Kansas Univ. Quart., vol. 2, pp. 123-124, 1894.

[6]Keyes, C. R., The Missourian series of the Carboniferous: Am. Geologist, vol. 23, p. 306, 1899.

[7]Haworth, E., Stratigraphy of the Kansas Coal Measures: Kansas Univ. Geol. Survey, vol. 3, pp. 93-94, 1898.

[8]Haworth, E., and Bennett, John: General stratigraphy, Kansas Univ. Geol. Survey, vol. 9, p. 76, 1908.

clusive. The upper limit of the formation was formerly drawn at a lower horizon, as shown by Prosser's definition of the base of the Wabaunsee[1], the next formation above.

MEMBERS OF THE SHAWNEE FORMATION.

Kanwaka shale member.[2]—The basal member of the Shawnee formation takes its name from Kanwaka, Kans., and was first applied by Adams. Haworth used the name "Lecompton" for this member, but Bennett had already given that name to the overlying limestone..

This member, with the Lecompton limestone and Tecumseh shale, represents the Platte[3] shale of Keyes, named from outcrops in Platte County, Mo.

Lecompton limestone member.—Above the Kanwaka shale is the Lecompton limestone,[4] named from exposures near Lecompton, Kans. The name Lecompton has been in general use since the first application.

Tecumseh shale member.[5]—This shale takes its name from Tecumseh, Kans. No other name is known to have been applied to this member. Broadhead's section, numbers 171 to 179, is a duplication, so that numbers 170, 180, and 181 represent the Tecumseh shale.

Deer Creek limestone member.[6]—The name of this limestone was taken from Deer Creek, east of Topeka, Kans. Haworth and Kirk previously used the name "Strawn"[7] for this limestone, but that name has been dropped by the Kansas Survey, as it had already been used for a Carboniferous formation in Texas by Cummins. Later the names "Calhoun,"[8] "Nodaway"[9] and "Forbes"[10] were also used for this member.

[1]Prosser, C. S., The classification of the Upper Paleozoic rocks of central Kansas: Jour. Geology, vol. 3, pp. 682-705 and 764-800, 1895.

[2]Adams, G. I., Stratigraphy and paleontology of the Upper Carboniferous rocks of eastern Kansas: U. S. Geol. Survey, Bull. 211, p. 45, 1903.

[3]Keyes, C. R., The Missourian series of the Carboniferous: Am. Geologist, vol. 23, p. 308, 1899.

[4]Bennett, John, A geologic section from Baxter Springs to the Nebraska State line: Kansas Univ. Geol. Survey, vol. 1, p. 116, 1896.

[5]Beede, J. W., The stratigraphy of Shawnee County, Kansas: Kansas Acad. Sci. Trans., vol. 15, pp. 27-34, 1898.

[6]Bennett, John, A geologic section from Baxter Springs to the Nebraska State line: Kansas Univ. Geol. Survey, vol. 1, p. 117, 1896.

[7]Haworth, E., and Kirk, M. Z., Kansas Univ. Quart., vol. 2, pp. 104-112, 1894.

[8]Beede, J. W., The stratigraphy of Shawnee County, Kansas: Kansas Acad. Sci. Trans., vol. 15, pp. 28-29, 1898.

[9]Gallaher, J. A., Bienn. Rept. State Geologist: Missouri Bureau of Geology and Mines, p. 53, 1898.

[10]Keyes, C. R., The Missourian series of the Carboniferous: Am. Geologist, vol. 23, p. 53, 1899.

Calhoun shale member.[1]—This shale was named from outcrops near Calhoun, Kans. In Iowa it thins, and, with the overlying Topeka limestone, was called the Braddyville limestone[2] by Smith.

Topeka limestone member.—The Topeka limestone[3] was named from Topeka, Kans., where it is extensively quarried. It is the equivalent of the "Hartford" limestone.[4]

Severy shale member.—The name Severy[5] was derived from Severy, Kans., which is built on this shale. It contains the Nodaway or Quitman coal, which is to be correlated with the coal mined in Osage County, Kans., and that near Topeka, Kans. (Osage-Topeka coal seam).

Howard limestone member.—Above the Nodaway coal, and forming its cap-rock, is the Howard limestone, named from Howard, Kans., and first used by Haworth in 1898. Gallaher the same year applied the name "Quitman"[6] to this member, from outcrops at Quitman, Nodaway County, Mo., but the Kansas name is here adopted as the term "Quitman" had already been used for Cretaceous rocks in Texas.

Scranton shale member.—The Scranton shale[7] takes its name from Scranton, Kans. Haworth says "Haworth, Hall and Adams called them the Burlingame shales and other names, but the name Burlingame was given to limestone above the shales at the same time." In view of this fact the name Scranton is here used. Smith later applied the name City Bluffs shale[8] to an interval in Iowa which includes the equivalent of the Scranton shale, the Howard limestone, and part of the Severy shale.

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[1]Beede, J. W., The stratigraphy of Shawnee County, Kansas: Kansas Acad. Sci. Trans., vol. 15, p. 29, 1896.

[2]Smith, G. L., Carboniferous section of southwestern Iowa: Iowa Geol. Survey, vol. 19, pp. 605-657, 1909.

[3]Bennett, John, A geologic section from Baxter Springs to the Nebraska State line: Kansas Univ. Geol. Survey, vol. 1, pp. 116-117, 1896.

[4]Kirk, M. Z., A geologic section along the Neosho and Cottonwood rivers: Kansas Univ. Geol. Survey, vol. 1, p. 80, 1896.

[5]Haworth, E., Stratigraphy of the Kansas Coal Measures (Doctor Adams' field work): Kansas Univ. Geol. Survey, vol. 3, p. 67, 1898.

[6]Gallaher, J. A., Bienn. Rept. State Geologist: Missouri Bureau of Geology and Mines, p. 54, 1898.

[7]Haworth, E., and Bennett, John, General stratigraphy: Kansas Univ. Geol. Survey, vol. 9, p. 112, 1908.

[8]Smith, G. L., Carboniferous section of southwestern Iowa: Iowa Geol. Survey, vol. 19, pp. 605-657, 1909.

WABAUNSEE FORMATION.

DEFINITION.

Wabaunsee,[1] like Shawnee, is a term derived from a Kansas county. The formation was first described by Prosser. He says "I have considered the base of this formation as defined by the top of the Osage coal horizon." This paper dealt with the section near Topeka, Kans., where, at that time, the Osage coal was supposed to be represented by a bed (the Silver Lake) above the Topeka coal. Later Beede[2] found the Osage coal to be the equivalent of the Topeka bed. The limestone over the Silver Lake (Elmo) coal was found to be lenticular and Prosser[3] re-defined the base of the Wabaunsee as at the bottom of the next limestone above, that is, the Burlingame (believed to be the same as the Tarkio of the present report). The later Kansas reports use the name Wabaunsee in this sense, which is the definition herein adopted. In 1899 Keyes proposed to revive the name "Atchison"[4] for the beds exposed in Atchison County, Mo., on the supposition that Broadhead had intended to use it as a geologic name. It is not believed, however, that Broadhead intended any such use of the term. Broadhead made a section of the rocks of Atchison County, but was unable to make the connection between it and the remainder of his section, and so published the two separately.

SUBDIVISIONS.

Tarkio limestone member.—Several names have been applied to this member. Through a miscorrelation it was called the Stanton by Swallow, who supposed it to be the limestone exposed at that place. Kirk named it the "Wyckoff,"[5] but that name had already been applied to an Ordovician limestone in Minnesota. The name Burlingame has been frequently used for what is believed to be this member. In 1901 Calvin named this limestone the Tarkio limestone,[6] from outcrops on Tarkio River, Page

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[1]Prosser, C. S., The classification of the Upper Paleozoic rocks of central Kansas: Jour. Geology, vol. 3, pp. 682-705 and 764-800, 1895.

[2]Beede, J. W., The stratigraphy of Shawnee County, Kansas: Kansas Acad. Sci. Trans., vol. 15, p. 29, 1898.

[3]Prosser, C. S., Revised classification of the Upper Paleozoic formations of Kansas: Jour. Geology, vol. 10, pp. 703-737, 1902.

[4]Keyes, C. R., The Missourian series of the Carboniferous: Am Geologist, vol. 23, pp. 298-316, 1899.

[5]Kirk, M. Z., The Neosho River section: Kansas Univ. Quart., vol. 2, Pl. III, 1894.

[6]Calvin, Samuel, Geology of Page County: Iowa Geol. Survey, vol. 11, pp. 397-460, 1901.

County, Iowa. Adams subsequently (in 1903) proposed "Barclay."[1] Although Mr. Greene has little doubt that the Tarkio limestone will prove to be the same as the Burlingame, in the absence of definite correlation with the Burlingame at the type locality, the name Tarkio is here used.

Undifferentiated beds.—In southern and central Kansas the section above the Burlingame limestone has been studied and the members have been named, but between these localities and Missouri River the region is covered by drift and the members have never been traced. The section in Missouri corresponds to the Willard shale, or possibly to the Willard shale, Emporia limestone, and Admire shale of the Kansas Survey but no correlation can be made at this time. In Iowa the name McKissicks Grove shale has been applied to all of the Pennsylvanian above the Tarkio limestone. An Iowa coal seam in this portion of the section has been called the Nyman, a name here used.

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[1]Adams, G. I., Stratigraphy and paleontology of the upper Carboniferous rocks of eastern Kansas: U. S. Geol. Survey Bull. 211, p. 51, 1903.

CHAPTER II.

DES MOINES GROUP.

GENERAL FEATURES.

The Des Moines group was originally separated from the upper part of the Pennsylvanian series on the supposition that it was formed in shallower and more disturbed waters. Although, as intimated in Chapter I, this supposition is not wholly correct, the grouping is retained for purposes of convenience of treatment, as it includes deposits of far more economic importance than those in the Missouri group. The most important economic deposits are in the lower formation of the group, the Cherokee shale, and consist of coal, shales, and clays used for fire-brick, pottery, common brick, tile, and other ceramic products, sandstone and other building stones, and a little zinc from the pocket outliers. Judged by analogy with the Kansas fields, from its composition, and from the rather meager results of drilling in Missouri, it is probable that any gas and oil accumulations that may exist in the State also lie in this formation.

The stratigraphy of the Des Moines group has recently been described in detail for every county in which it outcrops.[1] It is intended to elaborate in this chapter a few points of stratigraphic interest and to give only a bird's-eye view of the general features of the group.

AREAL DISTRIBUTION.

The Des Moines group outcrops in a broad zone from a short distance north of the southwest corner of the State northeastwardly to the northeast corner, with a tongue occupying the divide in Audrain and adjacent counties and numerous outliers east and southeast of the main body. The area of this surface distribution of outcrop is about 16,000 square miles. Northwest of this outcrop zone, the Des Moines dips northwest under the Missouri group to beyond the State boundaries, and the area

[1]Hinds, Henry, Coal deposits of Missouri: Missouri Bureau of Geology and Mines, vol. 11, 2d series, 1912.

MAJOR SUBDIVISIONS OF THE PENNSYLVANIAN IN KANSAS, MISSOURI AND IOWA.

Broadhead, 1868. Groups.	Broadhead, 1872. Northwestern Missouri	Broadhead, 1872. Adjacent to Pacific Railroad	Winslow, 1891 et seq	Keyes, 1892 et seq "Stages"	Keyes, 1895 et seq.	Haworth, 1895.	Prosser, 1895.	Bain and Leonard, 1898.	Keyes, 1897. Marbut, 1898.
A					Atchison shales (no definite boundaries).		Wabaunsee formation. (top of Osage coal horizon).		
B			Upper Coal Measures.	Missouri ("upper" Coal Measures).					
C.									
D	Upper Coal Measures								
E									
F		7. Upper Coal Measures.			Bethany Falls or later. Bethany limestone (no definite boundaries).				
		6. Mound Group.	Boundary not	Base = base of great limestone at Winterset.					
G	Middle Coal Measures.	5. Holden Group.	definitely defined. Middle Coal Measures.	Des Moines ("lower" Coal Measures).		Pleasanton shales.		(Correlated with Pleasanton).	Pleasanton shales.
		4. Lexington Group.				Pawnee limestone Oswego limestone		Appanoose.	Henrietta limestone or formation.
		3 Warrensburg Group							
H and I.	Lower Coal Measures	2. Knobnoster Group. 1 Clear Fork Group	Lower Coal Measures.			Cherokee shales.		Cherokee.	Cherokee shales.

Kansas Geological Survey, 1898. Divisions of the Kansas Coal Measures.			Schrader, 1908. Formations.	Schrader, 1908. Members.
B. UPPER COAL MEASURES.	6. Wabaunsee Formation.	A series of alternating limestones and shales to which individual names have not yet been given.		
		Burlingame limestone		
	5. Shawnee Formation.	Osage shales.		
		Topeka limestones.		
		Calhoun shales.		
		Deer Creek limestones.		
		Tecumseh shales.		
		Lecompton limestones.		
		Lecompton shales.	Elgin sandstone.	
	4. Douglas Formation.	Oread limestone.	Oread limestone.	
		Lawrence shales.	Buxton formation.	Not named.
		Garnett limestones.	Wilson formation.	Piqua limestone. Vilas shale. Allen limestone.
		Lane shales.		Concreto shale.
	3. Pottawatomie Formation.	Iola limestone.		Iola limestone.
		Thayer shales.		Upper part of Chanute shale.
		Erie limestones.	Drum formation.	Not named.
			Coffeyville formation.	Cherryvale shale (lower part of Chanute shale). Dennis limestone. Galesburg shale. Mound Valley limestone. Ladore-Dudley shale.
A. LOWER COAL MEASURES.	2. Marmaton Formation.	Upper Pleasanton shales.	Parsons formation.	Not named.
		Altamont limestone.		
		Lower Pleasanton shales.		
		Pawnee limestone.		
		Labette shales.		
		Oswego limestone.		
	1. Cherokee shales.	Cherokee shales.		

Kansas Geological Survey, 1909. Kansas Survey.	Vol. III. Vol. IX.	Faunal Divisions.		Formations	Classification in present report. Groups.	Formations	Members.
B. UPPER COAL MEASURES.	WABAUNSEE FORMATION.	SERIES. III.	Stage H.	Americus limestone.	MISSOURI	Wabaunsee formation.	Undifferentiated shales and limestones
				Admire shales.			
				Emporia limestone			
				Willard shales.			
				Burlingame limestone			Tarkio limestone
	SHAWNEE FORMATION.		Stage G.	Scranton shales.		Shawnee formation.	Scranton shale
				Howard limestone.			Howard limestone
				Severy shales.			Severy shale
				Topeka limestone.			Topeka limestone.
				Calhoun shales.			Calhoun shale
				Deer Creek limestone.			Deer Creek limestone
				Tecumseh shales.			Tecumseh shale.
				Lecompton limestone.			Lecompton limestone
				Kanwaka shales			Kanwaka shale
	DOUGLAS FORMATION.		Stage F.	Oread limestone		Douglas formation.	Oread limestone.
				Lawrence shales.			Lawrence shale with Amazonia limestone bed.
				Kickapoo limestone.			Iatan limestone
				Leroy shales			Weston shale.
	POTTAWATOMIE FORMATION.			Stanton limestone.		Lansing formation.	Stanton limestone.
				Vilas shales.			Vilas shale.
				Allen limestone.			Plattsburg limestone
				Lane shales.			Lane shale with Farley limestone bed
		SERIES II.	Stage E.	Iola limestone.		Kansas City formation.	Iola limestone
				Chanute shales.			Chanute shale with Raytown and Cement City limestone beds.
			Stage D.	Drum limestone.			Drum limestone
			Stage C.	Cherryvale shales			Cherryvale shale
				Dennis limestone.			Winterset limestone
				Galesburg shales			Galesburg shale
				Mound Valley limestone.			Bethany Falls limestone
				Ladore shales			Ladore shale
				Bethany Falls limestone.			Hertha limestone.
A. LOWER COAL MEASURES.	MARMATON FORMATION.	SERIES I.	Stage B.	Pleasanton shales	DES MOINES.	Pleasanton formation	Undifferentiated
				Coffeyville limestone.			
				Walnut shales			
				Altamont limestone.			
				Bandera shales			
				Pawnee limestone		Henrietta formation.	Pawnee limestone
				Labette shales.			Labette shale
				Fort Scott limestone			Fort Scott limestone
	CHEROKEE SHALES.		Stage A.	Cherokee shales.		Cherokee shale	Undifferentiated

within the State underlain by the group in this condition is about 8,000 square miles.

LITHOLOGIC CHARACTER.

The group is composed of shale, sandstone, limestone, clay, and coal, named in the order of abundance. In a few places the amount of sandstone equals that of shale and in parts of certain formations limestone is preponderant, but in general shale constitutes at least half of all the strata. The varieties and general characteristics of the constituents do not differ from those of the Pennsylvanian series as a whole, except, perhaps, that the limestones are more impure and not so crystalline as those of the Missouri group. The lithology will be discussed in greater detail in connection with the stratigraphy of the different formations.

THICKNESS.

Variations in the thickness of the Des Moines group depend largely upon changes in that of the Cherokee shale. The original thickness of the group in different parts of the zone of outcrop may be roughly estimated by combining the thicknesses of the three component formations at their nearest full outcrop. Direct and complete measurements have been determined in a few places in and near the zone of Missouri group outcrop, where drilling has been carried as far down as the Mississippian, and are: (1) Bedford, Iowa, 725 feet; (2) Cainesville, Harrison County, 864 feet; (3) Berlin, Gentry County, 882 feet; (4) Trenton, Grundy County, 585 feet; (5) Forest City, Holt County, 895 feet; (6) Saxton, Buchanan County, 756 feet; (7) Atchison, Kans., 813 feet; (8) Randolph, Clay County, 714 feet; (9) Kansas City, 669 feet.

SUBDIVISIONS.

The Des Moines group has been separated into three formations on lithologic grounds. These are the Pleasanton formation at the top, the Henrietta formation in the middle and the Cherokee shale at the base. The basis for the separation is primarily the greater proportion of limestone in the Henrietta and the more regular and persistent character of its individual beds, but the classification can not be said to be a particularly fortunate one. The Pleasanton was an epoch of irregular, near-shore, non-calcareous deposition, except near the Kansas line, and its sediments are a fairly good lithologic unit. Where there are one or two limestone beds near its base, however, as near the Kansas and Iowa boundaries, it is sometimes difficult to determine its lower limit. The Henrietta consists of the Pawnee and Fort Scott limestones and the intervening Labette shale, and contains, in general, a greater proportion of limestone than the other two formations. The upper part of the Cherokee, however, was deposited under as uniform conditions as any part of the Henrietta, and, in a few districts, is fully as calcareous. On practical grounds it may be objected that the Henrietta of central Missouri is too thin to be a useful cartographic unit.

CHEROKEE SHALE.

AREAL DISTRIBUTION.

The lowest formation of the Pennsylvanian series is the most important economically and outcrops in the largest territory. It forms the surface or is subjacent to the drift in a broad belt from Kansas northeast through Barton and Vernon counties to Iowa. One tongue projects eastward along the north line of the State through Scotland and Clark counties nearly to Mississippi River and another occupies the Mississippi-Missouri divide in Audrain, Boone, Callaway, Ralls, and Montgomery counties. There are outliers east and south of the main body for a considerable distance and it may be that the small pockets of Pennsylvanian materials found high on the Ozark Plateau are of Cherokee age. In north-central and northwestern Missouri the formation is concealed by younger Pennsylvanian rocks, but is shown by drill records to retain the characters of the zone of outcrop in all except possibly the extreme northwestern corner of the State.

LITHOLOGIC CHARACTER.

By far the greater part of the formation consists of shale, although there is a considerable quantity of sandstone in the lower part of the Cherokee of western Missouri and thinner beds interstratified with higher strata in all localities. There is a small area in Callaway and neighboring counties where limestone and clay are the main constituents, shale playing an unimportant role. In Johnson, Henry and Bates counties there are also exceptionally thick limestone beds, and thinner layers may be found in the upper part of the Cherokee in all counties except Barton and part of Vernon. Coal beds are scattered through all of the formation, but form a very small proportion of the total sediments. Both the limestones and the coals, however, are of much greater stratigraphic significance than their bulk seems to warrant, for they preserve their individual peculiarities over large areas and are markers by which may be fixed the position of the other beds in the stratigraphic column.

The Cherokee shale and the Mississippian beds were laid down under conditions of sedimentation that were evidently quite different, so that there is a corresponding difference in the rocks formed and little difficulty in distinguishing one from the other. Unlike the Cherokee, the Mississippian contains great beds of massive limestone with little shale, sandstone, or clay, and no coal. Moreover, the limestones of the Cherokee are in general separated from those of the Mississippian by several hundred feet of non-calcareous beds and are much more fine-grained and impure. Many limestones of the Cherokee contain numerous invertebrate remains that definitely establish their Pennsylvanian age, but the distinctly different aspect of Mississippian rocks ordinarily makes an appeal to paleontologic evidence unnecessary.

THICKNESS.

The Cherokee sea, advancing from the west or southwest, first entered Missouri between Kansas City and Forest City and stretched northeast as a long shallow arm to and beyond Worth, Harrison, and Mercer counties. In the area inundated by this invasion were formed earlier Pennsylvanian sediments than are to be found elsewhere in the State. In Holt County, at Forest City, the thickness of the Cherokee is 712 feet, in Buchanan County 530, in Platte 555, in Clay 460, in Jackson 430, in Livingston about 450, in Gentry 700, and in Harrison 653 feet. A drilling in Worth County did not reach the base of the formation, but indicates that the lowest Cherokee beds were deposited in that region. After the deposition of these first sediments the sea advanced upon the old Ozark land mass lying southeast of the arm just mentioned, but it was some time before it reached Howard, Monroe, and the counties lying farther east. The effects of this are shown in the absence of the lowest Cherokee beds along the present eastern limit of the main body of the Pennsylvanian and by the reduced thickness of the formation in the following counties; Putnam 350 feet, Adair 200 to 320, Linn 260 to 310, Carroll about 340, Ray 350 to 400, Lafayette 330, Johnson 220 to 350, Cass 390, Bates 325 to 370, Henry about 230, Vernon and Barton 370, Macon 175, Randolph 180, Howard 132, Boone 130, Callaway 108 and Audrain 75 feet. The country northwest of the first arm of the sea was not submerged for a long period, for a deep drilling at Nebraska City, Nebraska, not far from the northwest corner of Missouri, penetrated practically no Cherokee.

SUBDIVISIONS.

A number of names have been applied in a local sense by several authors to a few members of the Cherokee, but it is believed that the subject can be more simply treated by describing the beds in connection with the coals associated with them. The coal beds, stratigraphically as well as economically, are the most important members of the formation, and their distribution, characteristics, and nomenclature have been fully described in another report.[1] The use of a large number of member names in a formation as heterogeneous as the Cherokee is confusing to all but those who have made a special study of its stratigraphy.

The lowest beds of the Cherokee were laid down on the irregular surface of older rocks in more or less disconnected bays and estuaries. As a consequence they were formed under very changeable conditions and contemporaneous beds varied greatly from place to place. It was not until several hundred feet of strata had been laid down in the region first inundated by the sea and the transgression had reached nearly all of the area now occupied by the Pennsylvanian rocks that conditions of sedimentation became more stable and deposits more uniform. The upper 100 to 190 feet of Cherokee consists of beds that are so regular in character and distribution that individual members may be correlated with reasonable certainty across the entire State and beyond into Kansas and Iowa. The correlations of beds lower in the formation can be made only where their relations to the more persistent members can be determined. There are, therefore, stratigraphic grounds for dividing the Cherokee into upper and lower divisions, as was recognized and done by Marbut in Henry County[2]. Marbut considered the upper division to extend from the base of the Tebo coal to the top of the formation. It is true that the Tebo coal bed is fairly persist-

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[1]Hinds, Henry, Coal deposits of Missouri: Missouri Bureau of Geology and Mines, vol. 11, 2d series, 1912.

[2]Marbut, C. F., Geological description of the Clinton Sheet: Missouri Geol. Survey, vol. 12, pt. 2, p. 35, 1898.

Fig. A. Coal pocket at Monarch strip pit, Moniteau county.

Fig. B. Near view of same, showing pre-Pennsylvanian rocks on right.

ent and that it is the lowest bed that is so. Recent preliminary paleobotanic work by David White, however, indicates that the Bevier coal bed corresponds in age with the base of the Allegheny formation of Appalachian coal fields and that the scanty fossil plants found in beds below the Bevier probably indicate a Pottsville flora. There is also stratigraphic evidence that the Bevier coal correlates with the Murphysboro (No. 2) coal of Illinois, a bed that is certainly at or near the base of the deposits of Allegheny age. In view of these facts it seems most appropriate to consider the bottom of the Bevier coal the base of the upper part of the Cherokee. Should additional paleobotanic work substantiate the conclusions drawn from preliminary studies, it would then be advisable to consider the upper and lower parts of the Cherokee to be separate formations and to assign to them appropriate geographic names.

REGIONAL VARIATION.

In considering the changes in the Cherokee shale from point to point in Missouri, the outliers are first taken up, then follows the outcrop zone from Kansas northeast to the Iowa line, and then that portion of the formation that lies beneath younger rocks in the northwestern part of the State.

Pockets and Outliers.—Beyond the outcrop of the main body of the Cherokee there are numerous outliers composed chiefly of sandstone and shale with some intercalated clay and coal. The best known of these is in St. Louis County, where the clay deposits are very important and where there is also considerable limestone[1]. Other notable areas are in Shelby, Monroe, Montgomery, Saline, Cedar, Dade, Greene, Lawrence, and Jasper counties. Most of the outliers occupy depressions in Mississippian limestones and some, especially in southwestern Missouri, lie in long narrow valleys eroded in the pre-Pennsylvanian land surface.

Pockets are in one sense also outliers, but may be distinguished by certain unique features. Briefly stated, they are shale, coal, sandstone, and clay deposits laid down in sink holes or small depressions and surrounded by walls of limestone belonging to Mississippian and older formations. They occur in nearly all parts of the State outside the main Pennsylvanian body and are especially numerous in Lincoln, Callaway, Cooper,

[1]Fenneman, N. M., Geology and mineral resources of the St. Louis quadrangle, Missouri-Illinois: U. S. Geol. Survey Bull. 438, 1911.

Cole, Morgan, Moniteau, and southwestern counties. They are round or elliptical in horizontal cross-section, are commonly only a few hundred feet in width, and are in many cases as deep as they are wide. Many contain as much as 30 to 90 feet of coal, chiefly of the cannel variety, and have excited much comment. In most cases the component layers are saucer-shaped, dipping inward on all sides from the surrounding limestone walls, as though the entire mass had slipped down a considerable distance. Fractures and slickensides indicate that part of this slipping occurred after the consolidation of the materials, though many of the coal pockets probably sank during deposition, the action of the humic acids hastening the deepening of the sinks. Sinks that were deepened in this way, while sediments were accumulating were probably slightly above ground-water level at that time. Deposition in many sinks probably took place after the drainage outlets at their bases had been choked up as a result of a slight subsidence of the region in which they lie. Some of the shale and sandstone deposits may have been formed after the region was invaded by the continental sea, though this is not necessarily the case. Certainly those containing coal were deposited while the region was free from brackish or salt waters. It is probable that solution was renewed at the bottoms of the sinks whenever ground-water level was lowered as a result of post-Pennsylvanian regional movements and that many of the deposits are still sinking.

The age of the pockets is tentatively considered to be Cherokee, though so far as fossil and other available evidence shows, those in southern Missouri may be contemporaneous with other Pennsylvanian formations. In Callaway and other counties in which there are regularly bedded Cherokee deposits, the pockets are certainly of Cherokee age.

Barton and Vernon counties.—The Cherokee shale of Barton and adjacent counties differs from the outcropping formation farther northeast chiefly in the greater thickness due, in part at least, to a thickening of the shale and sandstone beds in both the upper and lower divisions.

GENERALIZED SECTION OF THE CHEROKEE SHALE IN BARTON AND SOUTHERN VERNON COUNTIES.

Number.	Stratum.	Thickness. *Feet.*	Distance from top. *Feet.*
1	Shale, black, slaty (top of Cherokee)	4	4
2	Coal	1	5
3	Shale, with some sandstone; poorly exposed	61	66
4	Limestone, dark-blue when fresh, weathers out in drab, diamond-shaped flags (hence "diamond-rock")	1	67
5	Shale, with one or more 6-inch limestone beds in places	6	73
6	Shale, black, slaty; with large and small calcareous concretions	3	76
7	Shale, light-drab, sandy	3	79
8	Shale, bluish-black	2 ½	81 ½
9	Coal (Mulky?)	1 ½	83
10	Shale, perhaps including sandstone	31	114
11	Shale, black, bituminous	3 ½	117 ½
12	Coal (Weir-Pittsburg Upper)	1 ½	119
13	Clay	12	131
14	Sandstone	8	139
15	Shale, slaty in lower half	13	154
16	Coal (Weir-Pittsburg Intermediate)	1	155
17	Clay	2	157
18	Sandstone	2	159
19	Shale, sandy, indurated at base	20	179
20	Coal (Weir-Pittsburg Lower [Bevier?])	2 ½	181 ½
21	Clay	3 ½	185
22	Interval containing sandstone and shale	50	235
23	Sandstone and clay, alternating	11	246
24	Shale, black, slaty, pyritiferous at base	7	253
25	Coal streak	—	253
26	Clay	3 ½	256 ½
27	Sandstone in upper part, slaty shale in lower	10 ½	267
28	Coal, including two feet of clay in middle	4	271
29	Clay	4	275
30	Shale, blue	3	278
31	Coal	1	279
32	Clay	4	283
33	Sandstone	4	287
34	Shale, slaty	4	291
35	Coal	1	292
36	Sandstone, with thin shale layer at top	33	325
37	Shale, slaty	6	331
38	Coal streak	—	331
39	Clay in upper half, slaty shale in lower	9	340
40	Coal	½	340 ½
41	Clay	8	348 ½
42	Shale, slaty	9 ½	358
43	Coal	1	359
44	Clay, pyritiferous	8	367
45	Mississippian limestone and flint	—	—

Numbers 1-9 of the above section are from outcrops near Eve, Vernon County, Nos. 11-21 from drillings near Yale, Kans., and outcrops north of Minden, Barton County, and Nos. 23-45 from a drilling in the valley at Liberal. The connection between the Mulky coal bed and the Weir-Pittsburg Lower is not absolutely fixed and, indeed, it is possible that the two beds are the same. The Mulky and its characteristic "diamond-rock" cap were not seen in the Liberal and Minden districts and so could not be tied to the Weir-Pittsburg Lower with certainty, though it is known that the latter lies about 180 feet below the top of the Cherokee shale. The strata below the Weir-Pittsburg Lower are evidently very irregular. In Dade, St. Clair, eastern Barton, and southeastern Vernon counties there is a conspicuous development of sandstone in the lower part of the Cherokee. Its exact stratigraphic position is doubtful. It may be that it is merely a shore phase of deposition and contemporaneous with shales and clays that were laid down farther from the Ozark land mass, though it is more probable that its western representative is No. 36 of the above section.

Bates and Vernon counties. In Bates and northern Vernon counties, where the connection of the lower beds of the Cherokee with those of the Henrietta formation can be easily deciphered in drill records and outcrop observations, the section can be more accurately described.

TYPICAL SECTION OF CHEROKEE SHALE IN BATES AND NORTHERN VERNON COUNTIES FROM DRILLINGS NEAR SPRAGUE AND RICH HILL

Number.	Stratum.	Thickness. *Feet.*	Distance from top. *Feet.*
1	Shale, blue and black (top of Cherokee)	6	6
2	Coal (Lexington)	½	6½
3	Clay	1½	8
4	Shale, in part sandy, with thin sandstone beds	81	89
5	Coal (Summit?)	½	89½
6	Clay	1½	91
7	Limestone	7	98
8	Shale, upper half slaty	14	112
9	Coal (Mulky?)	1	113
10	Clay	5	118
11	Shale, with thin sandstone bed at top	10	128
12	Coal (upper Rich Hill)	1½	129½
13	Clay	4½	134
14	Shale, drab to black	8	142

Fig. A. Upper and lower Fort Scott limestone at type locality, Fort Scott, Kans.

Fig. B. The "diamond rock" near Eve, Vernon County, showing typical jointing.

TYPICAL SECTION OF CHEROKEE SHALE IN BATES AND NORTHERN VERNON COUNTIES FROM DRILLINGS NEAR SPRAGUE AND RICH HILL—Continued.

Number.	Stratum.	Thickness. *Feet.*	Distance from top. *Feet.*
15	Coal (lower Rich Hill [Bevier?])	5	147
16	Clay	1	148
17	Shale, in greater part blue, black and slaty at base	28	176
18	Coal	1½	177½
19	Clay	1½	179
20	Shale, blue	2	181
21	Coal streak	—	—
22	Clay	4	185
23	Shale, sandy, including a bed of sandstone	38	223
24	Sandstone, gray and white when fresh	99	322
25	Coal	½	322½
26	Shale, blue to black, in part slaty	31½	354
27	Coal	1	355
28	Clay	4	359
29	Mississippian limestone	—	—

The beds in the above section, especially those overlying the lower Rich Hill coal, are remarkably persistent in a large territory. Individual members thicken and thin considerably from point to point, but the distance from the lower Rich Hill coal to the top of the formation varies only about 30 feet, being 170 in northwestern Bates County and 140 farther southeast. The only good stratigraphic marker in the section is No. 7. This limestone is variable in thickness, averaging about 7 feet, and is gray, irregularly bedded, and contains fossils with a purplish tinge. Where the bed is of full thickness, it has a lower division of 18 inches or less that is evenly bedded and vertically jointed, resembling No. 4 of southern Vernon County, with which it is to be correlated. The shale between it and the Mulky (?) coal bed is 10 to 40 feet thick.

The correlation of the beds of Bates County with those farther south is clear, for the lower Rich Hill coal bed is evidently the same as the Weir-Pittsburg Lower and other beds can be definitely placed by their relations to the thick coal. The correlation with the Cherokee of north Missouri is less certain, however, though the best stratigraphic and paleobotanic evidence now available points to the correspondence of the Bevier with either the lower or upper Rich Hill coal. The variable thickness of shale No. 11 is characteristic of the shale overlying the Mulky coal farther northeast, while the notable thickening of limestone No. 7 from a one or two-foot bed is a feature that has its homolog in the Mulky cap-rock of parts of Johnson, Callaway, and other counties. Sandstone No. 24, which is exceptionally thick beneath the Rich Hill district, probably lies at the same horizon as Broadhead's "Clear Creek sandstone" and is the arenaceous rock that outcrops so conspicuously in many parts of St. Clair and southeastern Bates County.

Some of the structural features of the southern Bates and northern Vernon County region are of unusual interest. In the mines in the lower Rich Hill coal at Panama, Rich Hill, and New Home, very strong dips have been encountered. In extreme cases the coal bed changes its level as much as 150 feet in less than half a mile, while dips sufficiently strong to render mine haulage a serious problem are by no means uncommon. These dips do not fall into alignment with any regular system of folding and are more numerous and stronger in shaft mines than would be suspected from an inspection of the higher strata at the surface. The regularity of the succession shown in drill records and outcrops precludes the supposition that many of the dips are depositional, yet some of them may be of that type. In the new drainage ditch 2 miles south of Prairie City, in the southeastern corner of Bates County (W.½ sec. 24, T. 38 N., R. 30 W.), the strata are very much disturbed, though slightly higher beds in neighboring country are horizontal or nearly so. The accompanying photographs (Pl. VI) show two of these exposures, one in which beds are warped, tilted, and faulted in at least two places, and another in which there is a sharp symmetrical anticline on a small scale, with dips of 45° on both limbs. These phenomena are probably due to different processes than those that affected the Rich Hill coal beds. The disturbed strata lie very near the base of the Pennsylvanian, for Mississippian limestone appears on the Osage River, one mile above Belvoir, little more than a mile distant. Their condition is due either to the proximity of the anticline that has brought the limestone to view or to collapsing of underground channels in the Mississippian limestone beneath them, a common cause of similar disturbances in the basal Cherokee of other localities.

Henry County.—Passing northeast into Henry County we may note the introduction of two thin limestone beds not present farther southwest and a thinning of the shale beds that consti-

Fig. A. Faulting in lower part of Cherokee shale, drainage ditch two miles south of Prairie City, Bates County.

Fig. B. Small anticline in same locality.

tute the bulk of the interval between the Bevier coal horizon and the top of the Cherokee, resulting in a closer approximation to the Cherokee section of north-central Missouri.

GENERALIZED SECTION OF CHEROKEE SHALE IN HENRY COUNTY

Number.	Stratum.	Thickness. *Feet.*
1	Shale, light at top, black and slaty at base; bears large concretions	4
2	Coal (Lexington)	1
3	Clay and shale	9
4	Limestone	2
5	Shale and sandstone; with thin and irregular coal bed at base; 25 to 50 feet thick	35
6	Limestone, gray; weathers rough on top; in places a foot or more of blue limestone at base; absent in places, 15 feet thick in others	8
7	Shale, slaty	4½
8	Coal (Mulky), absent in places	1
9	Shale, blue	30
10	Coal (Bevier), absent in places	1½
11	Clay, shale, and sandstone; 3 to 12 feet thick	8
12	Limestone, variable; absent in places, 6 feet thick in others	3
13	Shale, light at top, black and slaty below; locally with large concretions; absent in places	5
14	Coal (Tebo), absent in places	2
15	Shale and sandstone, with basins of coal distributed irregularly both stratigraphically and geographically, including the Mammoth coal bed 40 feet below the Tebo horizon, and the Jordan coal, 70-100 feet below the same horizon	80–230
16	Mississippian limestone	———

Number 6 of the above section is the bed previously mentioned as the only limestone of the Cherokee shale in the Rich Hill district. Between Rich Hill and Clinton it is thin and inconspicuous and is absent along the west edge of the county. In northeastern Henry County and southeastern Johnson, however, it is as thick as any of the limestones of the Henrietta formation. Near Windsor it is 4 to 15 feet thick, at Leeton 11 feet, and at Henrietta more than 8 feet, the Mulky coal bed being absent in all these localities. This exceptional thickness apparently led Marbut[1] to correlate the Mulky cap-rock of northeastern Henry County with the next higher conspicuous limestone, the Fort Scott, in the northwestern part of the county, where the lower bed is much thinner.

[1]Marbut, C. F., Geological descriptions of the Clinton and Calhoun sheets: Missouri Geol. Survey, vol. 12, pt. 2, pp. 1-191, 1898.

The Tebo coal bed and its associated limestone cap-rock are quite persistent in a large area, but are absent at Clinton, southeast of Calhoun, and near Urich. These beds extend southwest into Bates County, but at Rich Hill and farther south the cap-rock is lacking, though the coal may be represented.

The Bowen coal trough near Windsor and the Mammoth trough near Lewis present an interesting problem[1]. The two deposits are unique in character and similar even in minor details, yet the distance of the Bowen coal below the Mulky cap-rock and the Bevier coal would place it at the horizon of the Tebo coal, while the Mammoth trough is 40 feet below the typical Tebo coal and cap-rock. It is difficult to believe that the two deposits were not formed in narrow valley-like depressions under similar conditions. It is probable that they were contemporaneous and that subsequent to their deposition and before the formation of the Bevier coal bed, the Lewis area underwent greater relative subsidence and received a greater thickness of sediments than the Bowen area. It is unsafe to postulate in how large a region this southwestward tilting was effective, but the probability of its existence makes it difficult to correlate many of the lower beds of the Cherokee.

It is possible that the Jordan coal and the Bowen and Mammoth troughs are of nearly the same age, though the Jordan apparently corresponds with beds 175 feet below the Bevier coal horizon in the Rich Hill district. No direct tie can be made between the Jordan coal of the Deepwater district and the more persistent strata of the upper part of the Cherokee, but the best available evidence indicates that the coal lies 80 to 110 feet below the Bevier coal horizon. The determination of the exact stratigraphic position of the Jordan bed is particularly important because the shale just above it contains many species of plants that have been very fully described and compared with those in Appalachian formations by White[2]. As a result of the examinations of fossil plant collections from many horizons and areas, and a re-examination of the Jordan coal flora, White states the belief that the Jordan flora is much older than was supposed by him in 1898, being comparable to the flora of the uppermost Pottsville as that is now revealed (see p. 261).

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[1]Missouri Bureau of Geology and Mines, vol. 11, 2d series, pp. 179, 190, and 193, 1912. See also Geology of Calhoun Sheet, op. cit.

[2]White, David, Fossil flora of the Lower Coal Measures of Missouri: U. S. Geol. Survey Mon. 37, 1899.

Johnson County.—In central Johnson and neighboring counties on the north and northeast, most of the upper Cherokee strata assume characters that are persistent as far north as the Iowa line[1].

TYPICAL SECTIONS OF CHEROKEE SHALE IN CENTRAL JOHNSON COUNTY, FROM OUTCROPS AND DRILLINGS NEAR MONTSERRAT.

Number.	Stratum.	Thickness.	Depth.
		Feet.	*Feet.*
1	Shale, soft and argillaceous at top, black and slaty at bottom	3	3
2	Coal (Lexington)	1	4
3	Clay, with nodular limestone at base	4	8
4	Shale, yellow	10	18
5	Interval, chiefly shale; very variable in thickness,—average	20	38
6	Limestone, dark gray; compact; vertically jointed	2	40
7	Shale, in part slaty	8	48
8	Coal (Mulky)	2	50
9	Interval, chiefly shale	10	60
10	Shale, with a few thin limestone bands at top; black, slaty, and with small nodules at base.	21	81
11	Limestone, bluish-black, very fossiliferous	1	82
12	Coal (Bevier)	2	84
13	Clay, white	4	88
14	Limestone, blue to gray; irregularly bedded; nodular	3	91
15	Shale	2	93
16	Coal (Tebo)	2	95
17	Shale	17	112
18	Sandstone, reddish-brown; in part massive; in part thin-bedded	11	123
19	Shale, dark below, light above	15	138
20	Coal (Brushy Hill)	1	139
21	Clay	5	144
22	Shale	8	152
23	Coal	1	153
24	Clay	4	157
25	Shale	12	169
26	Coal	1	170
27	Clay	6	176
28	Shale	9	185
29	Coal	½	185½
30	Clay	4½	190
31	Shale, black, slaty, present only in places	—	—
32	Coal (Montserrat)	5	195
33	Clay, sandy	10	205
34	Shale, sandy at top, black at base	25	230
25	Sandstone; thin-bedded; firmly cemented	20	250
36	Mississippian flint and limestone	—	—

[1]The correlations in this report, and in volume XI of this series of reports, of coal and other beds in the Cherokee shale south of the counties bordering Missouri River are tentative. Reconnaissance field work in Central Johnson county indicates that the lower Fort Scott coal of Kansas may be the equivalent of the Mulky instead of the Lexington, the Lexington pinching out to the south.

The interval between the Bevier coal horizon and the top of the Cherokee does not differ in essential respects from that in Henry County, though it is to be noted that the cap-rock of the Mulky coal is thin and vertically jointed as in southern Vernon County. There are places, however, where it is slightly thicker and more irregularly bedded, so that it is very difficult in small exposures to distinguish it from the cap-rock of the Tebo coal. The shale between the Mulky coal and this cap-rock varies from 4 to 15 feet in thickness in Johnson County, the variation being due chiefly to drab, argillaceous shale that wedges into the interval in places. Little is known about the areal persistence and character of strata below the Tebo coal horizon, as they outcrop in only a few localities and have been drilled in only a few others.

Lafayette County.—Two other thin limestones appear in Lafayette County and are persistent as far north as Iowa: namely, the bottom-rock of the Lexington coal bed and the cap-rock of the Summit coal bed. While the Summit cap-rock may be present as No. 4 of the Henry County section, the Lexington bottom-rock is absent south and southwest of Lafayette County. In north Missouri it could be grouped more naturally with the strongly calcareous Henrietta formation above than with the argillaceous and arenaceous Cherokee shale, and this was done in Bain's "Appanoose formation" of southern Iowa. Consistency demands the placing of this bed in the Cherokee, however, as the coal above it has been correlated with a bed in Kansas that lies near the top of that formation.

GENERALIZED SECTION OF THE CHEROKEE SHALE IN LAFAYETTE COUNTY.

Number.	Stratum.	Thickness.	Distance from top.
		Feet.	*Feet.*
1	Shale, black, slaty	1 ½	1 ½
2	Coal (Lexington)	1 ½	3
3	Clay	4	7
4	Limestone, bluish-gray; rough-bedded; nodular	3	10
5	Shale, drab and blue	18	28
6	Limestone, blue when fresh, gray to drab weathered; in one bed; vertically jointed	1	29
7	Shale, black, slaty	3 ½	32 ½
8	Coal (Summit)	½	33
9	Clay, blue	6	39
10	Limestone; in places very concretionary	3	42
11	Shale, drab	2	44

GENERALIZED SECTION OF THE CHEROKEE SHALE IN LAFAYETTE COUNTY—Continued.

Number.	Stratum.	Thickness.	Depth.
		Feet.	*Feet.*
12	Limestone, bluish-drab, weathers brown; commonly in one bed and vertically jointed.....	2	46
13	Shale, at top drab and argillaceous, in lower part black, slaty, and with large and small oval limestone concretions....................	7 ½	53 ½
14	Coal (Mulky)............................	1 ½	55
15	Clay....................................	4	59
16	Shale, gray and drab, with intercalations of micaceous sandstone......................	41	100
17	Coal (Bevier)...........................	½	100 ½
18	Clay....................................	1	101 ½
19	Limestone, nodular......................	2 ½	104
20	Shale, in part drab, in part black and slaty....	15	119
21	Coal (Tebo).............................	1	120
22	Shale, with a few coal beds and several sandstone beds..................................	150	270
23	Sandstone, with thin coal beds and several shale beds; about............................	85	355
24	Mississippian limestone.................	—	—

Saline to Linn counties.—The part of the above section that lies below the Tebo coal is variable in character and thickness, the variation already noted in the thickness of the Cherokee in counties north of the Missouri River being largely due to thickening and thinning of these members and to the unconformity at the base. The section above the Tebo coal, though varying in minor details, is much the same in Saline, Ray, Carroll, Livingston, Linn, and Chariton counties, the greatest change being in the intervals just above and below the Bevier coal bed. In Ray County the Summit coal is represented only by carbonaceous shale, though the cap-rock is the same as in the Lafayette County section. In Carroll, Livingston, Linn, and Chariton counties the Lexington coal is absent, though its bottom-rock may be found in many places. In Livingston and northeastern Carroll there are only thin streaks of coal at the Mulky horizon, and another coal, the Bedford, appears between the Mulky and Bevier coal horizons. The Bedford is probably a split from the Bevier and lies about 95 feet below the top of the Cherokee and 15 feet above the Bevier. In this region the Tebo is 35 feet below the Bevier and the calcareous layers forming the Bevier bottom-rock are separated from a thin limestone cap-rock of the Tebo coal by about 15 feet of shale. In eastern Linn and

Chariton counties the Bedford and Bevier coal beds are commonly so close together as to form virtually one bed, the interval between them decreasing gradually toward the east. In these two counties the interval between the Bevier and Tebo coals is very irregular, in some localities 15 feet and in others as much as 75 feet. The distance of the Bevier coal from the top of the Cherokee is normally about 90 feet and from the Mississippian about 200 feet, the interval containing chiefly shale.

Macon and Randolph counties.—In Macon, Randolph and adjacent counties there is a slight change, as shown in the following table:

GENERALIZED SECTION OF THE CHEROKEE SHALE IN CENTRAL MACON AND RANDOLPH COUNTIES.

Number.	Stratum.	Thickness.	Distance from top.
		Feet.	*Feet.*
1	Shale, with coal streaks (horizon of Lexington coal)	5	5
2	Limestone, dove-color, irregularly bedded, nodular and with clay partings	7	12
3	Clay, white	4	16
4	Shale, in part sandy, with some sandstone	15	31
5	Limestone, blue to grayish-drab; in one layer with imperfect parting in center; vertically jointed	3	34
6	Shale, black, slaty	2½	36½
7	Coal (Summit)	1	37½
8	Clay	3½	41
9	Limestone, nodular	1	42
10	Shale, blue, in places with much irregularly bedded limestone and in others really a limestone with shale partings	12	54
11	Limestone, much like No. 5 but commonly less perfectly jointed and darker on weathered surfaces	3	57
12	Shale, black and slaty at base, grading to softer and lighter material at top; bears ovoid concretions in places	4½	61½
13	Coal (Mulky)	1½	63
14	Clay	3	66
15	Shale, drab, in part sandy, in places partly replaced by sandstone	20	86
16	Coal (Bevier)	4	90
17	Clay	1	91
18	Limestone, bluish-drab, mottled dark and light blue on fresh fracture; impure; nodular; weathers very unevenly at top	3	94
19	Shale, with some sandstone and one or two thin beds of limestone	20	114
20	Limestone, bluish-gray to drab; evenly bedded	1	115
21	Shale, in large part black and slaty; bears ovoid concretions	9	124

Fig. A. Limestone beneath Lexington coal horizon, weathered exposure.

Fig. B. Limestone beneath Lexington coal horizon, fresh exposure.

GENERALIZED SECTION OF THE CHEROKEE SHALE IN CENTRAL MACON AND RANDOLPH COUNTIES—Continued.

Number.	Stratum.	Thickness.	Distance from top.
		Feet.	*Feet.*
22	Coal (Tebo)	1	125
23	Shale, with much sandstone in places	70	195
24	Coal (Eureka)	1	196
25	Sandstone and shale	25	221
26	Mississippian limestone	—	—

While there are considerable variations in minor details, this section applies with remarkable fidelity to a large territory in the two counties. There is, in general, a thickening of the limestones to the south and a thinning of the shales to the east. Number 2 of this section is only about 4 feet thick in Macon County, but in Randolph it is a conspicuous 10-foot bed filled with large individuals of the coral Chaetetes and hence termed by Broadhead the "Chaetetes limestone," a name that is hardly appropriate, both because it is not geographic and because Chaetetes is locally abundant in other limestones in this and other districts.

The interval between the Mulky and Bevier coal beds is the most variable portion of the upper part of the Cherokee. In the eastern parts of the two counties it is quite thin, only six feet in places, but it thickens to the west and is 50 feet on the main branch of Chariton River. Its chief constituent is argillaceous or sandy shale, though in many localities, and especially where it is more than the average thickness, it contains considerable sandstone, much of which is cross-bedded and bears other evidences of deposition in disturbed waters. Though no two localities show exactly the same strata between the Bevier and Tebo coal beds, the general features of that interval are fairly persistent and well-marked. The beds between the Tebo and the base of the Cherokee are decidedly lenticular and range from 10 to 200 feet in thickness, the maximum being in Macon County.

Where exposures are poor, three coal beds of this section, with their associates, are apt to be confused in the field; namely, the Summit, Mulky, and Tebo. All are overlain with a few feet of black carbonaceous slaty shale with a limestone cap-rock. The cap-rocks display certain minor characteristics that make it possible for the trained observer to distinguish them in most localities, but in others it is almost impossible to do so unless other beds are also exposed in the neighborhood. The shale between both the Mulky and Tebo coals and their respective cap-rocks is slightly thicker and more argillaceous at the top than that on the Summit coal bed, and in many places is also distinguished by the presence of ovoid, calcareous concretions, or "niggerheads" of many sizes. The Summit is the only one of the three coal beds to possess a persistent limestone bottom-rock, though a very inconspicuous and discontinuous one locally underlies the Mulky. The Bevier bed is easily distinguished from other coals by its thickness in most of the area, by the absence of a limestone cap-rock, and by the presence of a very resistant and persistent bottom-rock that has certain unique characters not easily described.

Adair County and vicinity.—In Adair, Putnam, and Schuyler counties the Cherokee section is much the same as in Macon County. The Lexington coal is present in part of the area and its bottom-rock is commonly less than 3 feet thick and without Chaetetes. The cap-rock of the Summit coal is an impure black limestone rarely more than 2 or 3 inches thick, and the coal itself is only a few inches thick. The cap-rock of the Mulky coal is thinly developed in a large area, but the coal is known in only one locality. The shale and sandstone above the Bevier coal are 40 to 50 feet thick, and near Kirksville the shale facies is inconspicuous. North and west of Connelsville the Bevier coal splits into two beds, separated by 20 feet or less of shale and clay. The bottom-rock of the Bevier coal consists of two limestones, each less than a foot thick, though in a few places there is a nodular phase as in Macon County. The interval from this bottom-rock to the Tebo coal varies from 36 feet at Stahl to 53 feet near Kirksville. Cherokee strata below the Tebo coal horizon are chiefly shale and sandstone and vary 100 feet or more in thickness within distances of a few miles; the interval is as little as 60 feet in one drilling at Kirksville and as much as 217 feet near the Iowa line.

Broadhead constructed a generalized section for Linn, Sullivan, and Adair counties[1], including 85 beds, but owing to slight changes in the section from place to place, notably the absence of the Lexington coal in Linn County, duplicated parts of it.

[1]Broadhead, G. C., (Geology of) Linn, Sullivan and Adair (counties): Missouri Geol. Survey, Rept. for 1873-74, pp. 222-226, 1874.

Fig. A. Summit coal horizon and limestone cap rock on Medicine Creek, southern Grundy County.

Fig. B. Mulky coal horizon and limestone cap rock on Shoal Creek, Putnam County.

From his number 1 (Ladore shale) to number 62 (shale below the bottom-rock of the Bevier coal, the section is correct, but numbers 64 to 85 are repetitions of numbers 35 to 62. Numbers 38 to 62 and 65 to 85 are referred to the Cherokee shale. The coal Broadhead named the "Spring Creek" or "lower Spring Creek" and placed about 175 feet below its proper horizon is the Lexington bed. Norwood, however, suspected that the upper coal mined in this region was the same as that mined in Lafayette County (the Lexington). In Norwood's two sections for Putnum and Schuyler counties, published in the same volume, the beds below number 17 of the former and number 10 of the latter, are referred to the Cherokee shale.

Scotland and Clark counties.—In Scotland and Clark counties there are 150 feet or less of Cherokee strata resting on Mississippian, concealed nearly everywhere by thick glacial drift. These beds are chiefly shale, with sandstone in comparatively small amount, several coal beds of lenticular character, and a very few very thin and lenticular limestone beds. The exact stratigraphic position of these beds is still doubtful, though it may be that they lie at and just below the Bevier coal horizon, as do those of the nearest Illinois coal field, a short distance east of Clark County.

Monroe County.—In Monroe County, east of the area for which the last generalized section was given, the chief change from the succession in Randolph County is due to the overlap of the Pennsylvanian on the peninsula that in Cherokee time projected into northestern Missouri from the Ozark land mass. In the west the interval from the bottom-rock of the Summit coal to the Mulky coal is the same as in the generalized section. Farther east and southeast the cap-rock of the Mulky coal thickens to 8 feet near Madison and 15 feet near Santa Fe. Where it is thick it is rather thinly and irregularly bedded, is slightly crystalline in appearance, and at top is dove-colored and bears Chaetetes. The shale subjacent to the Mulky cap is 4½ to 8 feet thick, is black and slaty, contains numerous small flattened concretions, and, locally, larger ovoid limestone concretions, the latter in the lower part. The shale between the Mulky and Bevier coals thins to the east so as to be less than 5 feet thick near Paris. The Bevier coal is too thin to be of economic importance and disappears altogether in many places near the eastern edge of the county. Near Madison the Tebo is separated from the Bevier by 20 feet and less of material, chiefly shale, but near Paris and farther east the Tebo is absent and the Bevier coal horizon is separated from the Mississippian by only about 15 feet of clay.

Howard County.—In Howard County the section is much the same as in Randolph. The "Chaetetes limestone," the bottom-rock of the Lexington horizon, is nearly 10 feet thick and outcrops conspicuously in many places. The clay beneath the Summit coal contains nodules and thin beds of limestone that lie on the cap-rock of the Mulky coal, the latter being only a few feet below the Summit. The Mulky coal bed is absent in much of the county. The Bevier coal lies about 85 feet below the top of the Cherokee and the Tebo coal 25 feet and less below the Bevier. Below the Tebo there is an average interval of 20 feet, chiefly clay, to the Mississippian.

In his general section of Howard County[1] Norwood duplicated a large part of the Cherokee section because of a mistake in correlating outcrops near Sebree. He placed the beds seen in the cut west of Sebree (SW.¼ sec. 7, T. 50 N., R. 14 W.) above those at Digg's coal bank, whereas the lowest limestone at the coal bank is the highest in the cut. The Mississippian limestone outcrops that were seen near the cut, in the bed of Moniteau Creek, during the very dry summer of 1911, were probably covered with water during Norwood's visit or he would not have been led into this error.[2] Coal "D" of his general section is, therefore, the Tebo and lies below coal "E," the Bevier. His number 39, the bottom-rock of the Bevier coal, is the same as his number 60. If numbers 27-39 be omitted and numbers 40-51 substituted for numbers 61-62, his section becomes a good description of the rocks in this region. Broadhead noted the difficulties attached to applying Norwood's section to western and central Howard County and Norwood himself was forced to drop out 127 feet of material above coal "E" in order to apply his section to rocks near Burton. The "Ferruginous sandstone" of Broadhead and Norwood is probably a local development of Pennsylvanian sandstone, though there is no paleontological evidence on which to base this conclusion.

Boone County.—Southeastward across northeastern Howard County into central Boone County the change from the Randolph section is a gradual one and is due chiefly to a thinning

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[1]Norwood, C. J., Geology of Howard County: Missouri Geol. Survey, Rept. for 1873-1874, pp. 201-207, 212, 1874.

[2]The correct section is given in volume 11, 2d series, of this Bureau, pp. 204-205, 1912.

of various shale beds and a thickening and coalescing of certain limestones.

GENERALIZED SECTION OF THE CHEROKEE SHALE EAST OF COLUMBIA, BOONE COUNTY.

Number.	Stratum.	Average thickness.	Distance from top.
		Feet.	*Feet.*
1	Shale, with coal smut (horizon of Lexington coal bed)	5	5
2	Limestone, light-blue; irregularly bedded; nodular at top	5	10
3	Shale	9	19
4	Limestone, bluish to light-gray, in one bed; rings under the hammer	3	22
5	Shale, black, slaty	3	25
6	Coal (Summit)	1	26
7	Clay and limestone	2	28
8	Shale, both sandy and argillaceous, with lenses of sandstone	32	60
9	Coal (Bevier)	3	63
10	Clay, with limestone concretions in lower part	3	66
11	Limestone, dark-blue; weathers bluish-buff; nodular at top	2	68
12	Shale, dark below, light above	2	70
13	Coal	1	71
14	Clay and shale	5	76
15	Limestone, dark-blue to buff; with 2-foot shale parting near middle	10	86
16	Shale, dark, with numerous small concretions	2 ½	88 ½
17	Coal (Tebo)	½	89
18	Fire clay, white and variegated, thickness variable, average	20	109
19	Mississippian limestone	—	—

The shale at No. 3 of the above section thickens to 25 or 30 feet northwest of Columbia and the shale and sandstone at No. 8 are also variable in thickness and character, in places showing cross-bedding. The amount of limestone between the Bevier and Tebo beds, aggregating 10 feet, is greater in this locality than observed elsewhere. The thicknesses of these limestones and their intercalated shales change within short distances; more commonly there are three thin limestones, the upper two a split of the bottom-rock of the Bevier coal and the lower the even-bedded cap-rock of the Tebo coal. The coal at No. 13 is of local occurrence and the Tebo is not quite as persistent as in many other areas. The Mulky coal was found only at one place, as a coal streak at the top of No. 8.

Our Columbia section does not agree very well with one given by Broadhead[1] for the same locality. His numbers 2-15 correspond with the section given down to and including the Bevier coal bed, but the lower beds are quite different. It is believed that most of the strata included in Broadhead's numbers 16-19, inclusive, are duplications of beds listed in the upper part of his section and should be omitted.

Callaway County.—The thinning of the shales and the thickening and coalescing of the limestones above the Mulky coal horizon are carried still further in Callaway County, as shown in the following:

GENERALIZED SECTION OF THE CHEROKEE SHALE IN CALLAWAY COUNTY.

Number.	Stratum.	Average thickness.	Distance from top.
		Feet.	*Feet.*
1	Limestone, dove-colored; thin and irregularly bedded	20	20
2	Limestone, brownish gray to blue; in one bed; compact; vertically jointed	1½	21½
3	Shale, blue (horizon of Summit coal)	4½	26
4	Limestone, light-blue; thin and unevenly bedded; very impure; 2-16 ft.	10	36
5	Shale and clay, dark-drab, in places with streak or thin bed of coal at base (horizon of Mulky coal) 2 to 4 ft.	3	39
6	Shale and clay, drab; nothing to 10 ft.	5	44
7	Sandstone, commonly white and locally so calcareous as to resemble limestone; elsewhere brownish; 1 to 11 ft.	5	49
8	Shale, in many places bearing a thin, impure limestone "cap-rock"; 8 to 28 ft.	11½	60½
9	Coal (Bevier); 18 to 48 inches	2½	63
10	Clay; 1 to 4 ft.	2	65
11	Limestone, with thick shale partings; 1 to 11 ft.	2	67
12	Shale; nothing to 2 ft.	—	—
13	Coal (Tebo); nothing to 6 inches	—	—
14	Clay, variegated; good fire clay in lower part; 10 to 65 ft.	20	87
15	Sandstone, white to brown	2	89
16	Conglomerate; flint and a few limestone pebbles and boulders in a firm siliceous matrix; nothing to 50 ft.	15	104
17	Mississippian limestone	—	—

[1]Broadhead, G. C., Geology of Boone County: Missouri Geol. Survey, vol. 12, pt. 3, p. 384, 1898.

There is an average of 31 feet of limestone in the upper part of this section and in at least one place, west of Fulton, there are 38 feet of limestone broken only by 4 feet of blue shale. It is tentatively suggested that shale bed No. 3 of the Columbia section is replaced by limestone in central Callaway County, causing the limestones above and below it to become parts of one bed. The upper part of No. 1 of the Callaway section is, therefore, the highest limestone, the "Chaetetes limestone" in the Cherokee shale. No. 2 may be the cap-rock of the Summit coal, which it strongly resembles in the few places where it is well exposed. No. 4 is the bottom-rock of the Summit coal bed, combined with an exceptional development of calcareous material at its base much like that in the Higbee district of Randolph County, and with the cap-rock of the Mulky coal as it occurs in the region on the north. The rest of the section does not differ in essential particulars from that of the region on the northwest except that No. 11, the calcareous interval just below the Bevier coal, thins to the east and, with the Tebo coal below it, is absent in most of central Callaway County.

It must be admitted that the above correlations can not be made with any degree of certainty. Exposures on Cedar Creek, the boundary between Boone and Callaway counties, can be readily correlated with those in central Boone and the region farther northwest. The exposures on the east side of the divide which lies east of Cedar Creek are not so easily placed, however, for they include more limestone in closely associated beds than is known elsewhere in the Cherokee shale of Missouri. It has been suggested orally by two geologists familiar with the area that this great development of limestone should be correlated with the calcareous beds just below the Bevier coal in Boone and other counties. In the light of the recent field work carried on in all the coal fields of the State, however, the interpretations given above seem better to fit all the facts. It is to be noted that similar exceptionally great thicknesses of the limestone just above the Mulky coal horizon have been observed also in southeastern Johnson and northeastern Henry counties and in Bates County.

Audrain County.—In Ralls, Montgomery, and eastern Audrain counties the Cherokee section partakes of some of the characters it has in Callaway County combined with some of those of Monroe and Randolph counties. Its total thickness is about 75 feet though the upper portion has been spared by erosion only near Martinsburg and Wellsville. The top member is an irregularly bedded limestone about 7 feet or more thick that corresponds to the upper part of No. 1 of the Callaway section and is the bottom-rock of the Lexington coal. Between it and the thin cap-rock of the Summit coal are 6 feet of shale partially filled with many lenticles of limestone, corresponding to No. 3 of the Columbia section and the lower part of No. 1 of the Callaway section. Near Wellsville the upper part of this bed is so calcareous as to be indistinguishable from the limestone above it. The cap of the Summit coal and subjacent slaty shale are much the same as in Boone County, though the coal itself is very irregular in thickness. Below the variable, though thin, underclay of the Summit coal are 2 to 15 feet of limestone that is irregularly bedded at the top and more massive at the base. Locally the lower few feet resemble the even-bedded and thin cap-rock of the Mulky coal of Macon County, while the upper portion has its counterpart in the irregularly bedded shale and limestone that lie on the Mulky coal cap in Randolph County. Separated from the limestone by 7 to 11 feet of black, slaty shale containing lenses and ovoid concretions of limestone is a very persistent thin coal bed, the Mulky. The Bevier coal was found only in Ralls County, where it is a thin and nonpersistent bed a few feet below the Mulky. Elsewhere the 20 to 40 foot interval between the Mulky and the flint breccia and Mississippian limestone is occupied only by fire and other clays. These clays have much the appearance of being the stratigraphic equivalents of the basal clays of Boone and Callaway counties and of the famous Cheltenham fire clay of the St. Louis district.

Northwest Missouri.—Turning now to the northwestern part of the State, where the Cherokee is concealed beneath a cover of younger Pennsylvanian rocks, we find that the main features of the succession are little changed. In many of the drillings the Summit and Mulky coal beds and their limestone cap-rocks are absent, but the Bedford coal is quite persistent and the Bevier bed with its distinguishing limestone bottom-rock can be detected in nearly every good drilling at depths of 100 to 150 feet below the top of the Cherokee. The good drill-records made at Atchison and Leavenworth, and in less degree the one at Forest City, show that during upper Cherokee time conditions of sedimentation along Missouri River at the west boundary of the State were almost identical with those in north-central Missouri. Strata below the Bevier can not be correlated so easily and consist only of shale with interbedded sandstone, coal, and clay. The shales constitute by far the greater part of the formation, but the proportion of sandstone increases toward the base, so that there is comparatively little shale for 100 feet or more above the Mississippian. The increase in the thickness of the Cherokee in parts of northwestern Missouri, definite figures for which have already been given, is due almost entirely to variation in the portion that lies beneath the Bevier coal horizon, and is caused by the thickening of individual members and, more especially, by the introduction at the base of beds that were laid down before the area farther east and southeast was submerged. Details of the stratigraphic succession where drillings have penetrated the Cherokee are shown in another publication.[1]

HENRIETTA FORMATION.

AREAL DISTRIBUTION.

Overlying the Cherokee shale is a series of limestones with interbedded shales and sandstones that has been termed the Henrietta formation. Filling a small interval between the Cherokee and Pleasanton formations and commonly outcropping at the top of either present or pre-glacial escarpments, it forms the surface rock over a comparatively small area. The main outcrop stretches across the State from the west edge of Vernon to the Iowa line north of Putnam and Schuyler counties, with more or less extensive outliers in Randolph, Howard Boone, Callaway, Audrain, and Montgomery counties. West of its outcrop it may be recognized in practically all drillings penetrating its horizon. Its distance from the outcrop of the Mississippian varies from one to 50 miles, usually nearer the larger figure. The outcrop in northern Missouri is somewhat problematical in places, because of the thick cover of glacial drift.

LITHOLOGIC CHARACTER.

The upper and lower limits of the Henrietta formation are marked by two limestones that are persistent throughout most of its area. The middle of the formation, one-half or more of the whole, consists of shale, sandstone, and one or two thin limestones. In the southern part of its area nearly half the formation

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[1]Hinds, Henry, The coal deposits of Missouri: Missouri Bureau of Geology and Mines, vol. 11, 2d series, 1912. See especially pp. 104, 112, 130, 131, 152, 156, 157, 164, 166, 169, 170, 173, 213, 214, 302, 303, 327, and 420.

is limestone. Farther north the whole formation thins, but as the thinning of the limestones is proportionately greater than that of the shales, the latter form two-thirds or three-fourths of the entire thickness. In most of the State there is no coal in the Henrietta, but in the southwest and west there are one or two very thin beds in the Labette shale member and one bed that is interstratified with the shale included in the Fort Scott limestone member.

THICKNESS.

In Vernon and Bates counties the Henrietta is 90 to 110 feet thick. Northeastward to Linn and Macon counties there is a persistent and uniform thinning, so that 15 feet is the maximum thickness observed in Macon County. From Macon northward to the Iowa line there is a steady increase in thickness, so that in Putnam there are 40 to 50 feet of strata. In the southeastern outliers, mentioned above, the upper part of the formation has been eroded away in most places, but in Howard County all the beds remain and aggregate 26 feet. Northwest of its outcrop zone the Henrietta probably averages close to 50 feet.

SUBDIVISIONS.

The Henrietta has been divided into three members, the Pawnee limestone at the top, the Fort Scott limestone at the base, and the Labette shale between them. The Fort Scott member consists of an upper and a lower limestone separated by a shale bed.

REGIONAL VARIATION.

The order of this discussion will be to follow the outcropping zone from southwest to northeast and then to consider northwestern Missouri, where the formation is concealed by younger rocks.

Barton and Vernon counties.—The basal portion of the Henrietta outcrops on one or two high mounds in northwestern Barton County and the higher beds cap the divides along the western border of Vernon. The type locality of the lowest member, the Fort Scott limestone, is at Fort Scott, Kansas, a few miles west of the State line (see fig. A, plate V). The Fort Scott section[1] is about as follows:

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[1]Bennett, John, A section from Fort Scott to Yates Center: Kansas Univ. Geol. Survey, vol. 1, pp. 86-98, 1896.

HENRIETTA FORMATION NEAR FORT SCOTT, KANSAS.

Number.	Stratum.	Thickness.	Distance from top.
		Feet.	*Feet.*
1	Limestone, in upper 25 feet heavy-bedded and containing quantities of the coral *Chaetetes milliporaceous*, and thin seams of gypsum in clay partings. Below this the layers are somewhat evenly bedded. Maximum exposed on Pawnee Creek (Pawnee limestone member)	35	35
2	Shale, arenaceous and micaceous; at State line there are 2-3 feet of shelly limestone 16 feet from top; near top and bottom are layers of bituminous shale, with thin coal beds in places, and two other thin streaks of bituminous matter dividing the whole into three nearly equal parts (Labette shale member).	60	95
3	Limestone, upper part unevenly bedded with *Chaetetes milliporaceous*, lower layers somewhat evenly bedded, with vertical seams (upper limestone of Fort Scott member)	10–14	107
4	Shale, clay and bituminous, the latter forming the greater part; near the middle is a thin coal bed and near the summit a yellow clay streak (middle part of Fort Scott member)	7	114
5	Limestone, "cement rock," light gray, weathering buff, with large crinoid stems, 1 ½ inches in diameter (lower limestone of Fort Scott member)	4 ½	118 ½

The Henrietta in Barton and Vernon counties closely resembles that at Fort Scott, though the Pawnee limestone is probably not more than 20 feet thick. The Pawnee forms a reddish soil through the weathering of its iron content and is rather cherty. In one place on the north end of the mound in secs. 6 and 7, T. 34 N., R. 32 W., the coal mentioned as lying between the two limestones of the Fort Scott member attains a thickness of 14 inches and is the thickest coal bed found in the Henrietta of Missouri.

Bates County.—As shown by numerous detailed drillings, the Henrietta of Bates County is remarkably uniform as a whole, the thickness varying between 90 and 110 feet. The Pawnee limestone varies from 12 to 37½ feet in thickness, is gray and cherty, and in many parts of the county forms the bottom rock of the Mulberry coal. The Labette shale is 35 to 62 feet thick and in most of the county prevailingly sandstone. At the top is shale underlain by a blue limestone about five feet thick and closely resembling the lower limestone of the Fort Scott member. This resemblance is strengthened by the black slaty shale and thin coal bed (Butler seam) underlying it in places. At the bottom, a few feet above the upper limestone of the Fort Scott member, is another thin but fairly persistent coal seam, in places overlain by two or three feet of limestone. The remainder of the Labette is heavy bedded sandstone 25 feet or more thick and apparently replacing the lower coal in places. In the eastern part of the county this sandstone grades down through thin-bedded sandstone and sandy shale to argillaceous shale. Above the sandstone is another bed of clay shale and the whole is about 60 feet thick.

The upper limestone of the Fort Scott member is 15½ to 23 feet thick and more thinly bedded than the Pawnee limestone. The shale between the upper and lower limestones of the Fort Scott member varies from 2½ to 10 feet thick, is black and slaty in the upper part, and in many places there is a six-inch coal bed below the slaty portion. Below the black shale or coal there is a bed of clay resting on the lower limestone of the Fort Scott. The latter resembles its homolog of the type locality, though it is absent in some drill records and as much as 20 feet thick in others. In many places it is underlain by black shale and coal.

In Broadhead's generalized section of Bates, Vernon, and Barton counties [1], his number 67 is the Pawnee, 56-66 the Labette, 55 the upper limestone of the Fort Scott and 50 the lower limestone of the Fort Scott, giving the Henrietta a thickness of 69 feet, rather under the normal because of the small thickness assigned to the Pawnee and Fort Scott members.

A typical section of the Henrietta is shown in the log of a drilling near Sprague (SW. ¼ NE. ¼ sec. 10, T. 38 N., R. 32 W.), the upper part of which is given below:

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[1] Broadhead, G. C., General section of the southwest coal field in Bates, Vernon and Barton counties: Missouri Geol. Survey, Rept. for 1873-1874, pp. 60-61, 1874.

DRILLING NEAR SPRAGUE, BATES COUNTY.

Number.	Stratum.	Thickness.		Depth.	
		Ft.	*in.*	*Ft.*	*in.*
1	Soil, etc.	11		11	
2	Shale, yellow	4		15	
3	Shale, blue	30		45	
4	Coal (Mulberry)	2	4	47	4
5	Clay (base of Pleasanton formation)	4	8	52	
6	Limestone (Pawnee)	18	6	70	6
7	Shale, slaty (top of Labette)	1	8	72	2
8	Shale, blue	2	4	74	6
9	Limestone	7	6	82	
10	Shale, slaty (horizon of Butler coal)	5	6	87	6
11	Clay	3		90	6
12	Sandstone	26	4	116	10
13	Coal		4	117	2
14	Clay (base of Labette)	4	10	122	
15	Limestone (upper limestone of Fort Scott member)	21		143	
16	Shale, slaty	3		146	
17	Clay	5	2	151	2
18	Limestone (lower limestone of Fort Scott member)	10	4	161	6

Henry County.—The Henrietta formation was first described in detail in the quadrangle reports on Henry County. Marbut[1] states that "The formation is essentially the northeastward extension of the Fort Scott and Pawnee limestones and the shales included between them in Kansas, as defined by Swallow and later by Haworth" and gives the following section:

MARBUT'S GENERALIZED HENRIETTA SECTION (HENRY COUNTY).

Number.	Stratum.	Thickness.
		Feet.
12	Limestone	5
11	Interval (probably shale)	50
10	Clay	4
9	Limestone	1
8	Shale	8
7	Limestone	2
6	Shale, black, fissile	2½
5	Coal	1
4	Shale	7
3	Limestone	1
2	Sandstone and shale	15
1	Limestone	5
		101½

[1]Marbut, C. F., Geological descriptions of the Clinton and Calhoun sheets: Missouri Geol. Survey, vol. 12, pt. 2, pp. 1-104, 1898.

At the time Marbut did the Henry County field work the Henrietta formation had not been traced from the Kansas State line. Recent field work by Mr. Greene has shown No. 12 to be the Pawnee limestone, 10-11 the Labette shale and 9 and 7 the upper and lower limestones of the Fort Scott member, respectively. No. 1 of this section is correlated with a rather persistent limestone in the upper part of the Cherokee shale. As shown in the foregoing section, both the Pawnee and upper limestone of the Fort Scott are considerably thinner than in Bates County, partly, perhaps, because they are commonly exposed in escarpments where solution or erosion has reduced their thicknesses. Both are known to be of greater thickness a few miles north and west of the area studied by Marbut. On the divide between Deepwater Creek and Grand River the limestone taken by Marbut as the base of the Henrietta thins out or is represented by a thin layer of limestone nodules. Consequently in the western part of the Clinton quadrangle the base of the Henrietta was originally mapped as the base of the Fort Scott limestone, while in the Calhoun quadrangle it was a lower bed in the Cherokee shale.

Cass County.—In southeastern Cass County, a few miles northwest of the Clinton quadrangle, a drilling penetrated the lower part of the Henrietta and the upper part of the Cherokee. The drilling was begun on Walnut Creek (SW. ¼ sec. 34, T. 44 N., R. 29 W.), below the Pawnee limestone.

DRILLING THREE MILES EAST OF GARDEN CITY, CASS COUNTY.

Number.	Stratum.	Thickness.		Depth.	
		Ft.	*in.*	*Ft.*	*in.*
1	Soil and clay	6		6	
2	Shale, clayey	4		10	
3	Coal		5	10	5
4	Clay (base of Labette shale member)	5	7	16	
5	Limestone (upper limestone of Fort Scott member)	14		30	
6	Shale, slaty	1	4	31	4
7	Coal	1	8	33	
8	Clay	3		36	
9	Shale, clayey	3		39	
10	Limestone (lower limestone of Fort Scott member)	6		45	
11	Sandstone and shale, alternating (top of Cherokee)	36		81	
12	Shale, slaty	2		83	
13	Coal	1	6	84	6
14	Clay	2		86	6
15	Shale, clayey	34	6	121	
16	Limestone (Marbut's base of Henrietta)	10		131	
17	Coal		10	131	10

Farther north in Cass County, at Pleasant Hill, a drilling showed the Pawnee to be 5 feet thick, the Labette 63½ feet, and the upper limestone of the Fort Scott 10 feet. Below this is (1) 7 feet of dark shale and limestone, (2) 15 feet of shale, dark blue and red, and (3) 2 feet of dense blue limestone. It is not known whether the lower limestone of the Fort Scott is (1) or (3).

Johnson County.—On the divide in southern Johnson County there are many outcrops of the Henrietta and practically the full formation extends east to Sutherland. The following record was furnished by Mr. J. B. Scott of Windsor, Mo.:

SHAFT AT SUTHERLAND, JOHNSON COUNTY.

Number.	Stratum.	Thickness.	Depth.
		Feet.	*Feet.*
1	Dirt	9	9
2	Rock (Pawnee limestone)	8	17
3	"Soapstone" (Labette shale)	20	37
4	"Slate" (Labette shale)	3	40
5	Coal (Labette shale)	1	41
6	Clay (Labette shale)	2	43
7	Rosk (upper limestone of Fort Scott member)	11	54
8	Black clay	5	59
9	"Soapstone"	11	70
10	Rock (lower limestone of Fort Scott member)	4	74
11	"Slate" (top of Cherokee shale)	3	77
12	Coal	$1\frac{1}{6}$	78
13	"Soapstone, fire-clay and boulders"	61	139
14	Rock (Marbut's base of Henrietta)	14	153
15	"Slate"	2	155
16	"Soapstone"	12	167
17	Coal	2	169

On Blackwater drainage both the Pawnee limestone and Labette shale are somewhat thinner than in the southern part of the county. The upper limestone of the Fort Scott is apparently thinner but retains its thin-bedded character and gray color. The lower limestone of the Fort Scott is two to three feet thick, blue, and weathers buff. It outcrops as a single layer or in two or more thin beds. The shale between the two limestones is irregular both in thickness and lithology, but in all outcrops contains a layer of black bituminous shale. One or two thin layers of limestone occur in places. The thickness of the Fort Scott varies from about 10 to 30 feet.

North of Holden is the following outcrop of the Fort Scott limestone:

PART OF FORT SCOTT LIMESTONE NORTH OF HOLDEN.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone, gray; thin-bedded, cherty (upper bed of the Fort Scott)	15	
2	Shale, drab at top and bottom, dark in middle	2	
3	Limestone, gray, even bedded, jointed		6
4	Shale, dark	2	
5	Limestone, blue, surface slightly wavy and covered with fucoidal markings		1–6
6	Shale, drab at top, black and slaty below (horizon of upper Fort Scott coal)	2	
7	Shale, black, soft		6

No. 2 or 4 of this section may be the Lexington coal horizon and No. 6 the Summit coal horizon. Nearby are some mines in a bed equivalent to the lower Fort Scott coal of Kansas. In the shale over-lying the coal are large, round concretions of limestone that contain fossils similar to those found in the roof shale of the Mulky coal in north-central Missouri.

Lafayette County.—Northward, in eastern Jackson, Lafayette, and Saline counties the Pawnee limestone is commonly 4 or 5 feet thick, though in a few drillings it is 7 or 8 feet. The Labette shale contains much limestone, and in a few places has a 10-inch coal seam and in others thin limestones. The thickness of the Labette varies from 12 to 26 feet, averaging about 20 feet. The Fort Scott member is extremely variable, the two limestones with the intervening shale being reported in drillings as from 13 to 37 feet thick, averaging about 20 feet: the upper limestone is a white or gray limestone, about 8 feet thick as a rule but varying from 3 to 12 feet; the lower limestone, varying from 4 to 9 feet in thickness, is a blue or gray limestone, differing, however, from its exposures in the type locality in being thin-bedded. No generalization can be made for the shale between the two limestones as it varies from a mere film to 20 feet in thickness, averaging about 6 feet. In places it contains so much calcareous material that it is almost a limestone, and in others is a black shale or clay.

Marbut,[1] in mapping the Lexington and Richmond quadrangles, drew the base of the Henrietta formation at nearly the same horizon as in Henry County; that is, at the base of a thin

[1]Marbut, C. F., Geological descriptions of the Lexington and Richmond sheets: Missouri Geol. Survey, vol. 12, pt. 2, pp. 193-308, 1898.

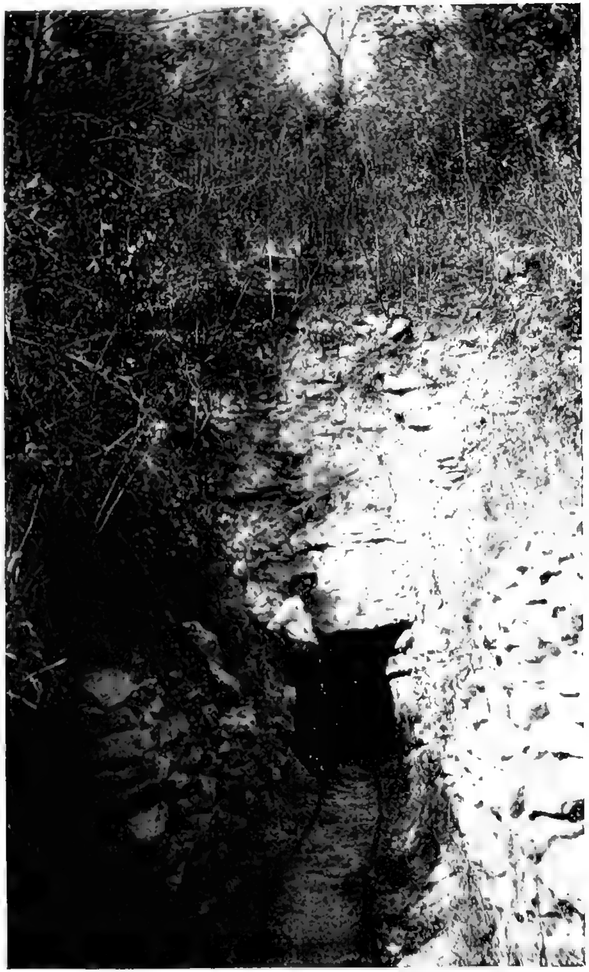


Fig. A. Lexington coal bed and overlying limestones, Lakeview, Ray County.

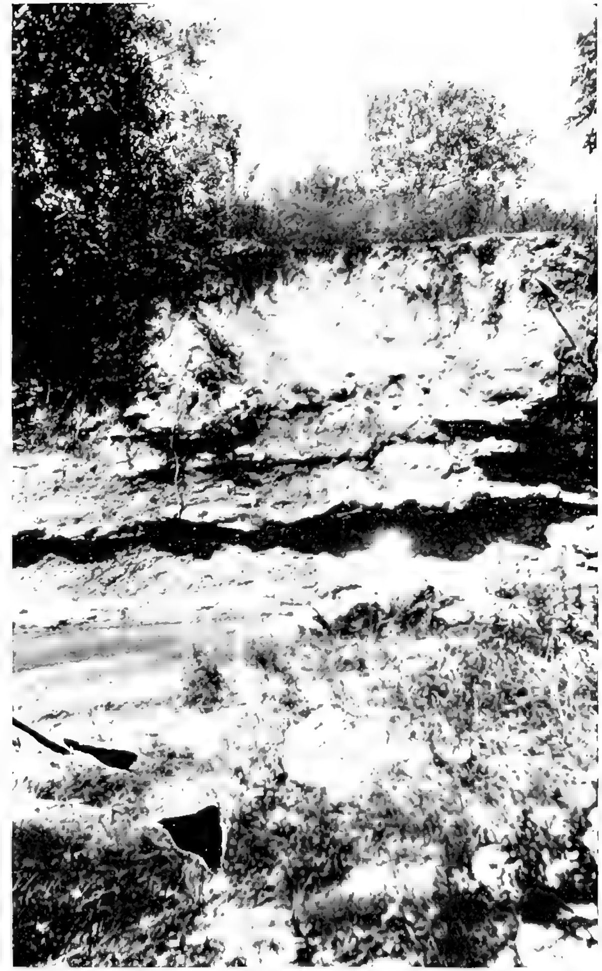


Fig. B. Part of Henrietta formation near Kirksville, Adair County.

limestone associated with the Summit coal and 30 or 40 feet below the base of the Henrietta as defined in this report. In the eastern part of Lafayette County, the "Middle Coal Measures" as defined by Winslow[1] correspond with the Henrietta of Marbut except that they include the Mulky coal and its underclay at their base.

Ray and Carroll counties.—Across Missouri River in Ray County there is scarcely any change in the thickness or lithology of the members of the Henrietta except that in many places the lower limestone of the Fort Scott is, perhaps, slightly thinner. Marbut's section gives a total thickness of 57 feet for the formation. Farther east, in Carroll County, all the members are thin, especially the Labette shale, and the total thickness of the formation is not more than 30 or 35 feet.

HENRIETTA FORMATION WEST OF TINA, CARROLL COUNTY.

Number.	Stratum.	Thickness.	Distance from top.
		Feet.	*Feet.*
1	Limestone, gray, nodular (Pawnee)	3	3
2	Shaly slope (Labette)	15	18
3	Limestone, blue, weathers buff } (Fort Scott)	2	20
4	Shale, drab, green, and red } (Fort Scott)	5	25
5	Limestone, gray to buff } (Fort Scott)	5	30

Chariton County.—Very little of the Henrietta is exposed in Chariton County, as most of it has been eroded away. On Mussel Fork near Westville there are a few patches of beds resembling those in Carroll County.

Livingston County.—The Henrietta is the same in southeastern Livingston County as at Tina, Carroll County. Farther north, in the vicinity of Wheeling, the Pawnee limestone is absent, either because it was never deposited or because it was removed by Pennsylvanian erosion in some districts. In the northern part of Livingston and in Grundy County there are very few outcrops of the Henrietta. At Trenton the shales are thin, and the limestones almost unrecognizable, though near Laredo the formation is about 25 feet thick.

Linn County.—The formation varies from 25 to 30 feet thick in Linn County. In the Santa Fe railroad cut northeast of Bucklin, on the east county line, the following section was measured:

[1]Winslow, A. W., The Higginsville sheet: Missouri Geol. Survey, pp. 1-17 and map, 1892.

HENRIETTA FORMATION NORTHEAST OF BUCKLIN, LINN COUNTY.

Number.	Stratum.		Thickness.		Distance from top.	
			Ft.	*in.*	*Ft.*	*in.*
1	Limestone, gray; nodular at top; weathers buff or gray (Pawnee member)		3	9	3	9
2	Shale, drab, greenish, and black; some layers calcareous (top of Labette member)		5		8	9
3	Limestone nodules, gray; six inches to		1	4	10	1
4	Clay, drab, with calcareous band in middle		6		16	1
5	Shale, purplish		1		17	1
6	Shale, drab, argillaceous		1	5	18	6
7	Shale, calcareous (base of Labette member)		1	3	19	9
8	Limestone, buff; argillaceous; nodular	(Fort Scott	2	6	22	3
9	Shale, drab to buff; calcareous	lime-	2	6	24	9
10	Limestone, gray; argillaceous; in thin irregular beds	stone member)	4	5	29	2

Macon County.—There are few outcrops in Macon County that show all of the Henrietta. Fragmentary exposures indicate a continued eastward thinning of the Labette shale and Fort Scott limestone. West of Atlanta the thickness of the whole formation was found to be only about 15 feet, the minimum noted in its entire outcropping area. From Linn and Macon counties northward to Appanoose County, Iowa, the thickness gradually increases.

Sullivan and Adair counties.—Drill and shaft records at Milan and Boynton show the thickness of the Henrietta to be 29 to 34 feet.[1] One mile east of Youngstown, the most southerly point in Adair County at which the whole formation was seen, the following beds were measured:

SECTION EAST OF YOUNGSTOWN.

Number.	Stratum.	Thickness.	Distance from top.
		Feet.	*Feet.*
1	Limestone, gray, heavy layer (Pawnee member)	2	2
2	Slope, shaly (top of Labette member)	8	10
3	Limestone, unconsolidated nodules	1	11
4	Shale, dark-drab	2	13
5	Limestone, buff; nodular at top	2	15
6	Shale, dark-drab	4½	19½
7	Limestone, purplish, fine-grained	½	20
8	Shale, drab	8	28
9	Limestone, gray, compact, single layer (base of Fort Scott member)	1	29

[1]See Mo. Bureau Geology and Mines, vol. 11, 2d series, pp. 406-407, 1912.

In Broadhead's section of Linn, Sullivan, and Adair counties [1] a number of beds were duplicated. In the first part of this section numbers 19-37 are referred to the Henrietta formation and in the last part number 64, a duplication of numbers 34-37, is also referred to the Henrietta. The Putnam and Schuyler county sections published by Norwood in the same volume are approximately correct, numbers 3-17 of the former and numbers 1-10 of the latter being referred to the Henrietta formation. Attention has been called to this duplication in our discussion of the Cherokee shale.

Putnam County.—The Henrietta formation is well exposed in Putnam County and attains there its maximum thickness for northern Missouri.

SHAFT OF UNIONVILLE COAL COMPANY, UNIONVILLE, PUTNAM COUNTY.

Number.	Stratum.	Thickness.	Depth.
		Feet.	*Feet.*
1	Drift clay	26	26
2	Shale (base of Pleasanton formation)	4	30
3	Limestone (Pawnee member)	4	34
4	Shale, red (top of Labette member)	4	38
5	Sandstone, firmly cemented	7	45
6	Shale and sandstone, alternating	8	53
7	Shale (base of Labette member?)	3	56
8	Limestone, "water rock"	3	59
9	Shale, dark blue	13	72
10	Limestone, gray, "10-inch cap"	$1\frac{1}{3}$	$73\frac{1}{3}$
11	Shale	6	$79\frac{1}{3}$
12	Limestone, blue; "cap-rock" (base of Fort Scott member)	2	$81\frac{1}{3}$
13	"Slate and clod" (top of Cherokee shale)	2	$83\frac{1}{3}$
14	Coal (Lexington)	—	—

As shown by this record the total thickness of the Henrietta is $51\frac{1}{3}$ feet. At other places in the county the thickness varies from 40 to 45 feet, depending largely on the thickness of the Labette shale. The latter is apparently thicker where sandy than where it is mostly clay shale.

Bain, in his report on Appanoose County, Iowa,[2] which is just north of Putnam and Schuyler counties, grouped the Henrietta and a few other beds in a formation he named the

[1] Broadhead, G. C., (Geology of) Linn, Sullivan, and Adair (counties): Missouri Geol. Survey, Rept. for 1873-1874, pp. 222-226, 1874.

[2] Bain, H. F., Geology of Appanoose County: Iowa Geol. Survey, vol. 5, pp. 377-394, 1895.

"Appanoose," a term that is in general use by Iowa geologists. His section, somewhat condensed, is as follows:

"APPANOOSE FORMATION" IN APPANOOSE COUNTY, IOWA.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
17	Limestone, gray, sub-crystalline; known among the miners as the "floating rock"	2–4	
16	Shale, argillaceous; color variable	12–30	
15	Limestone; heavy ledges; the "fifty-foot limestone"	4–10	
14	Shale, argillaceous; blue and red in color	14	
13	Shale, arenaceous; frequently forming a well defined sandstone	8	
12	Shale, argillaceous; blue to gray	10	
11	Limestone, somewhat variable in thickness; known as the "seventeen-foot limestone" or "little rock"	1–3	
10	Shale, sometimes gray; frequently bituminous and pyritiferous	7	
9	Limestone, sometimes gray, and coarsely subcrystalline; sometimes fine-grained, bituminous, and grading into the shales above and below; known as the "cap rock"	2–4	
8	Shale, usually bituminous, and known as "slate"; occasionally in part soft and clay-like; then known as clod, at times heavy and homogenous non-fissile, in which form it is known as "black bat"	1-3	
7	Coal, upper bench, usually	1	8–10
6	Clay parting, "mud band"		2– 3
5	Coal, lower bench, usually		8–10
4	Clay parting, the "dutchman"		½
3	Coal, frequently not so pure		2–3
2	Fire clay	1–6	
1	Limestone, "bottom rock"	3	6

Nos. 2-7 are correlated with the Lexington coal and, with No. 8, are at the top of the Cherokee shale. No. 9 is correlated with the lower limestone of the Fort Scott and 11 with the upper limestone of the Fort Scott, 12-14 with the Labette shale and 15 with the Pawnee limestone. The beds above, Nos. 16 and 17, are referred to the lower part of the Pleasanton shale on the basis of the field work recently carried on in Missouri.

Southeastern outliers.—Southeast of the main outcrop of the Henrietta are a number of more or less extensive outliers in Randolph, Howard, Audrain, Boone, Callaway, and Montgomery counties. The Henrietta formation of Randolph and Howard counties is about 25 feet thick and is similar to that of Chariton, Linn, and Macon counties.

TYPICAL SECTION OF HENRIETTA FORMATION IN RANDOLPH AND HOWARD COUNTIES.

Number.	Stratum.	Thickness.	Distance from top.
		Feet.	*Feet.*
1	Limestone, gray; rough-bedded; impure; with specks of calcite (Pawnee member)	2	2
2	Shale, light-buff, with small marble-like concretions (top of Labette member)	3	5
3	Coal, streak	—	—
4	Shale, drab; calcareous at top (base of Labette member)	12	17
5	Limestone, blue; weathers drab; rough on top; in one layer (top of Fort Scott member)	2	19
6	Shale, drab; with thin lenses of limestone	1	20
7	Limestone; dark-blue to dove; irregularly bedded above, massive below (base of Fort Scott member)	6	26

All the members of the formation in this region outcrop only on the divide north and south of Armstrong and in small scattered areas in the upper part of Bonne Femme and Moniteau creek drainages. The easternmost undoubted exposure of a Henrietta bed is a short distance from Columbia, Boone County, where a part of the lower limestone of the Fort Scott can be distinguished. The "Chaetetes limestone" at the top of the Cherokee shale can be seen on many ridges and it is probable that wherever it outcrops large outliers and fragments of the lower limestones of the Fort Scott have escaped erosion and lie concealed beneath the heavy drift cover. The same reasoning applies also to the outliers in Boone, Callaway, Audrain, and Montgomery counties, where areas containing the highest Cherokee beds are mapped as also containing some Henrietta. It is possible that the upper part of the very thick limestone at the top of the Cherokee in the last three counties named is of Henrietta age, the thin shale between the "Chaetetes limestone" and the lower part of the Fort Scott having disappeared, the two limestones forming one massive stratum.

Northwestern Missouri.—Northwest of the outcrop zone of the Henrietta, in northwestern Missouri, the formation dips beneath younger rocks. Drilling in this region invariably shows the limestones and other beds of the formation at their proper horizons except in a few places where they have apparently been removed by erosion and replaced by shales and sandstones of the Pleasanton formation. In much of the region it is easy to recognize the Pawnee limestone at the top of the Henrietta formation because of the absence of limestones in the basal Pleasanton, but the exact delimitation of the base of the Henrietta in drill logs is a more difficult problem. As shown elsewhere, there are two or three fairly persistent limestone and coal beds near the top of the underlying Cherokee shale and in some cases the line of demarkation between these two formations is very indistinct.

In Jackson and southern Clay counties the Henrietta is reported 50 to 60 feet thick and varies little from its nearest outcrops. Farther north in Clay County 80 to 107 feet of limestone and shale have been penetrated below the Pleasanton, the lower part probably belonging in the Cherokee. At Leavenworth and Atchison, Kansas, the thickness is apparently close to 50 feet, as it is also at Saxton and Lathrop, Missouri. In northern Clinton County not over 30 feet of strata can be referred to the Henrietta in the Cameron drilling, but in that at Stewartsville the amount of "rock" reported in the Des Moines may indicate a greater thickness.

In Caldwell County the Henrietta formation is usually found to be about 40 feet thick, but at Hamilton there are only 13 feet of strata that can be assigned to it. The drilling at Gallatin, Daviess County, penetrated about 20 feet of "conglomerate" and interbedded shale which is believed to be the Henrietta. Westward on the same fork of Grand River, the Henrietta was pierced at Gentryville, Gentry County, by a core drill, but unfortunately all consolidated material, regardless of its nature, was reported simply as "rock." As nearly as could be ascertained, however, the Henrietta is 73 feet thick and the Pawnee limestone at its top is 17 feet thick. At Maryville the log of a core drilling shows 59 feet of limestone and shale in the approximate stratigraphic position commonly occupied by the Henrietta, but drillings in Iowa seem to indicate that part of this may be Pleasanton.

In the western part of the State the lower part of the Pleasanton apparently includes much limestone, rendering very difficult the exact determination of the Pleasanton-Henrietta boundary. On the basis of a comparison of the Forest City drill record with those at Atchison, Kans., and Maryville, Mo., the thickness of the Henrietta at Forest City appears to be about 70 feet, although some limestone is present to as much as 118 feet above the base of the formation.

A number of drillings in Mercer and Harrison counties have penetrated far into the Cherokee shale, but in most of them the greater part of the Henrietta has been replaced by Pleasanton beds. In this district the most common thickness of the Henrietta is 40 to 50 feet where the whole formation is present. Three drillings near Lineville, Mercer County, failed to penetrate any limestones that could be correlated with those of the Henrietta, and it is probable that they were removed by erosion during Pleasanton time.

The northward extension of the Henrietta (termed Appanoose in Iowa) and Pleasanton formations in southern and central Iowa has been ably discussed by Bain and Leonard.[1]

PLEASANTON FORMATION.

AREAL DISTRIBUTION.

The Pleasanton formation is the upper of the three formations of the Des Moines group. From the Kansas State line to Grand River in Livingston County it outcrops in the face of the escarpment capped by the limestones at the base of the Kansas City formation and extends eastward to the top of the escarpment formed by the Henrietta formation, occupying a belt 5 to 20 miles wide. North of Grand River its outcrop abruptly widens, averaging nearly 50 miles and extending from the Kansas City escarpment to the Chariton River or farther east. In Howard County there is a small outlier. The outcrop is shown on the State geologic map.

LITHOLOGIC CHARACTERS.

By far the greater part of the Pleasanton is shale, but sandstone is abundant and is preponderate in places. Thin limestones are present in Bates County and in the northwestern part of the State, as shown in drillings, but in the greater portion of the area of outcrop limestone is absent or represented only by one or two thin beds. A thin coal seam (Ovid) is fairly persistent near the top and another (Mulberry) lies near the base. The latter is an important bed in Bates County and its possible equivalent has been mined for local consumption in Livingston County. One or two other thin beds are locally present. On the whole the lithologic character of the Pleasanton is

[1]Bain, H. F., and Leonard, A. G., The Middle Coal Measures of the western interior coal field: Jour. Geology, vol. 6, pp. 577-588, 1898.

extremely irregular, probably because of both contemporaneous erosion and of exposure to atmospheric denudation for a short time. In many places in the northern part of the State the lower 5 to 20 feet of the Pleasanton consist of red, white, or green shale. In some localities there are one or more thin limestones 15 to 70 feet above the base of the Pleasanton, probably in part correlatives of the Altamont limestone of Kansas geologists. It is a question, however, whether the limestone tentatively correlated with the Altamont lies at the same horizon in every instance. Above this limestone the shale of the Pleasanton apparently grades laterally through sandy shale and shaly thin-bedded sandstones to heavy-bedded or massive sandstone that is locally accompanied by conglomerate and in many places rests on lower Pleasanton or even older rocks. That this sandstone is of the same age as that occupying the Warrensburg and Moberly channels is within the bounds of possibility.

THICKNESS.

In Bates County the Pleasanton is more than 200 feet thick. Northeastward along the outcrop there is a steady thinning to Adair and Putnam counties, where it is about 100 to 125 feet thick. West of the outcrop, too, a thinning to the north has been noted in drill-records, so that in Buchanan, Clay, and Clinton counties the thickness is only 120 feet. Still farther north, however, in Nodaway, Harrison, Mercer, and Grundy counties, the formation again thickens to about 150 feet. Although the figures given are probably close to the average, there is considerable variation, even within comparatively small areas.

SUBDIVISIONS.

Although five subdivisions have been described and named in Kansas, the formation is too heterogeneous in most of Missouri to justify the naming and mapping of members. It is possible that more detailed work in Bates and Cass counties may reveal the equivalents of the members in Kansas, though they are certainly not persistent farther north, particularly in north-central Missouri, where the formation has been carefully examined. At the base of the formation, resting on the Pawnee limestone, many sections show red and green shale or clay, in places containing ferruginous concretions. Above this red shale there are one or two thin coal beds overlain by limestone in one or more thin beds. Both the limestones and the included shale are very fossiliferous and in Putnam, Sullivan, and Mercer counties may well be termed a *Trepospira sphaerulata* zone. The relations of this zone to the red and green shale are not known but there is some evidence of a slight local uncomformity. In Carroll, Livingston, Linn, and Adair counties there is a somewhat thicker limestone that may be stratigraphically the equivalent of the *Trepospira sphaerulata* zone and is here tentatively correlated with the Altamont limestone of Kansas. Above this and below the Ovid coal (near the top of the Pleasanton) is an unconformity that has been noted in nearly all of the north-central counties. Sandstone that is probably of upper Pleasanton age rests on the shale above the limestone (Altamont?) or on lower beds, even on those stratigraphically 50 or 60 feet below the horizon of the top of the Cherokee shale. Directly beneath the sandstone there is in many places a thin coal bed with a black slaty shale roof and in others a conglomerate (Chariton conglomerate of Bain) which usually grades up into the sandstone.

The unconformity mentioned in the last paragraph may be wide-spread and closely connected with the channel fillings known as the Warrensburg and Moberly sandstones, which are discussed in a separate chapter.

REGIONAL VARIATION.

Bates County.—In the greater part of the Pleasanton area of Bates County the base of the formation is well marked by the Mulberry coal, separated from the top member of the Henrietta (Pawnee limestone) by a few feet of clay. South of Osage River the Mulberry coal is overlain by shale having a maximum thickness of 65 feet, above which is a limestone that is perhaps the equivalent of the Altamont of Kansas. North of the Osage limestone lenses appear in the shale over the Mulberry coal, as shown in the following drill record near Merwin (NE. ¼ SE ¼ sec. 5, T. 41 N., R. 33 W).

DRILLING NEAR MERWIN, BATES COUNTY.

Number.	Stratum.	Thickness.	Depth.
		Ft. in.	*Ft. in*
1	Soil	15	15
2	Clay, sandy	5	20
3	Sandstone, soft	8	28
4	Shale	16	44

DRILLING NEAR MERWIN, BATES COUNTY—Continued.

Number.	Stratum.	Thickness.		Depth.	
		Ft.	*in.*	*Ft.*	*in.*
5	Shale, black, slaty	3		47	
6	Clay	9		56	
7	Limestone, soft	8		64	
8	Shale	21		85	
9	Limestone and sandstone	6	6	91	6
10	Shale, blue at top, light below	18	8	110	2
11	Limestone	5		115	2
12	Shale	2	4	117	6
13	Limestone, shelly	9		126	6
14	Shale, blue	1		127	6
15	Coal (Mulberry)	2	7	130	1
16	Clay	4		134	1
17	Limestone (Pawnee)	—		—	

The upper part of the Pleasanton is shown in a section at the east end of the long mound in T. 42 N., R. 32 W.

PLEASANTON FORMATION SOUTHWEST OF ADRIAN.

Number.	Stratum.	Thickness.	Distance from top.
		Feet.	*Feet.*
1	Limestone (Hertha limestone member of Kansas City formation)	—	—
2	Slope, covered	10	10
3	Shale, shandy; concealed in places	85	95
4	Slope, covered	30	125
5	Sandstone, heavy bedded	5±	130
6	Shale, drab; clayey at top; concealed at base	25	155
7	Shale, black, slaty	1±	156
8	Clay and shale	4	160
9	Sandstone, calcareous; almost a limestone	2	162
10	Shale, drab, clayey	6	168

North of Adrian the Pleasanton contains much sandstone.

Near Amoret the distance between the Mulberry coal and the lowest limestone of the Kansas City formation was found to be 167 feet and to the top of the ridge 222 feet. West of Passaic the total thickness of the Pleasanton, as measured by barometer, was 185 feet.

Johnson, Cass, and Jackson counties.—Broadhead determined the thickness of the Pleasanton formation in Johnson, Cass, and Jackson counties to be 176 feet and constructed the generalized section given below in modified form.

PLEASANTON FORMATION IN JOHNSON, CASS, AND JACKSON COUNTIES.

Number.	Stratum.	Thickness.	Distance from top.
		Feet.	*Feet.*
1	Shale, bituminous	1½	1½
2	Shale, argillaceous, or porous sandstone	13½	15
3	Limestone, sandy	1	16
4	Sandstone, calcareous; 3 inches of coal at base	1½	17½
5	Shale, sandy	35½	53
6	Coal, a few inches	—	—
7	Shale, clayey	15	68
8	Sandstone, buff	4	72
9	Sandstone and shale	45–55	117
10	Limestone	2	119
11	Shale, marly, and limestone nodules	7	126
12	Shale, olive and purple	10	136
13	Shale, sandy, and shaly sandstone	22	158
14	Coal (Holden)	1	159
15	Shale	6	165
16	Limestone	2	167
17	Shale	9	176

The average thickness of the Pleasanton in Jackson County, as shown in ten drillings in or near Kansas City, is about 174 feet. A few layers of limestone have been reported in drillings, but the most noticeable stratum is one of red shale somewhat below the middle of the formation. It is shown in the log of a shaft near where 56th Street crosses Blue River:

SHAFT OF CLAY MINE AT KANSAS CITY, MO.

Number.	Stratum.	Thickness.	Depth.
		Feet.	*Feet.*
1	Limestone (Bethany Falls)	22	22
2	Shale, slaty (Ladore)	4	26
3	Limestone (Hertha)	16	42
4	Sandstone (top of Pleasanton formation)	7	49
5	Shale	4	53
6	Sandstone	1½	54½
7	Shale	12½	67
8	Sandstone	6	73
9	Shale	39	112
10	Sandstone	2	114
11	Shale	16	130
12	Sandstone	1½	131½
13	Shale, light-colored	10½	142
14	Sandstone	6	148
15	Shale; red at base	8	156
16	Sandstone	12½	168½
17	Shale	22	190½
18	Sandstone	8	198½

SHAFT OF CLAY MINE AT KANSAS CITY, MO.—Continued.

Number.	Stratum.	Thickness.	Depth.
		Feet.	*Feet.*
19	Shale (base of Pleasanton formation)	8	206 ½
20	Limestone (top of Henrietta formation)	6	212 ½
12	Shale	4	216 ½
22	Limestone, shelly	5	221 ½
23	Shale	4	225 ½
24	"Rock, hard"	6	231 ½
25	Sandstone	4	235 ½
26	Shale; light-colored at top, blue below	11	246 ½

Lafayette County.—One mile west of Napoleon Broadhead found the thickness of the Pleasanton to be about 165 feet and saw no limestone in a rather poor exposure. According to Marbut the average thickness of the formation near Wellington, Odessa, and Lexington is 150 feet.

Ray County.—Across the Missouri River in Ray County the Pleasanton also averages about 150 feet. Marbut[1] gives a generalized section as follows:

PLEASANTON FORMATION IN RAY COUNTY.

Number.	Stratum.	Thickness.
		Feet.
1	Shale, argillaceous, reddish	20
2	Shale, sandy and argillaceous, brown and reddish	80
2	Coal	¼
4	Shale, sandy	25
5	Sandstone	5
6	Shale, blue and red, argillaceous	30

Near the top of the formation is a thin coal bed (Ovid) that appears at this horizon in many places along the outcrop of the Pleasanton in northern Missouri.

Carroll County.—In Carroll County the Pleasanton is about 150 feet thick. Near the middle is a thin lenticular limestone, below which is red shale over sandstone and sandy shale to within 10 to 20 feet of the base. At the base of the formation is a layer of red and green shale containing a great number of heavy purplish or reddish-brown, ferruginous concretions.

[1] Marbut, C. F., Geology of the Richmond quadrangle: Mo. Geol. Survey, vol 12, pt. 2, p. 274, 1898.

At one place near the north line of the county the total thickness of the Pleasanton is 122 feet.

Caldwell County.—The Pleasanton of this county resembles that of Carroll and is about 140 feet thick. The formation is chiefly shale, the lower third containing interbedded sandstone. In a few places the Mulberry coal has been reported at the base, and it is a significant fact that the coal is present only where there is sandy shale or sandstone just above its horizon, but absent where the basal Pleasanton is a red shale. The red shale is known to some drillers in this part of the State as "Kimball."

Livingston County.—North of Caldwell County the stratigraphy of the Pleasanton is somewhat complicated by the presence, in places, of heavy-bedded sandstone and thin conglomerates that rest on various members of the Pleasanton or even on lower beds.

At the east end of the high hill at Utica there are:

SECTION NEAR UTICA.

Number.	Stratum.		Thickness.	
			Ft.	*in.*
1	Limestone (Hertha)		—	—
2	Sandstone and shale	Pleasanton formation	140	
3	Coal	Pleasanton formation		12–18
4	Sandstone and shale	Pleasanton formation	22	10
5	Limestone (Pawnee)		—	—

The base of this section is about 20 feet above the water in Grand River, though 150 feet west only sandy shale and sandstone appear above the river. Broadhead attributes this discrepancy to a fault, but there is at least the possibliity of an unconformity. About one-half mile above this (NW. ¼ NE. ¼ sec. 18, T. 57 N., R. 25 W.) the limestones at the top of the Henrietta appear above water, with a thin coal seam 5 or 6 feet above them. A few feet higher there is a considerable thickness of massive, micaceous, cross-bedded sandstone. From the coal to the top of a hill capped by the Bethany Falls limestone the vertical distance is 165 feet, by barometer. The lower part of the Pleasanton contains much sandstone up the west fork of Grand River to at least as far as Gallatin, west of which only the upper portion of the formation is exposed.

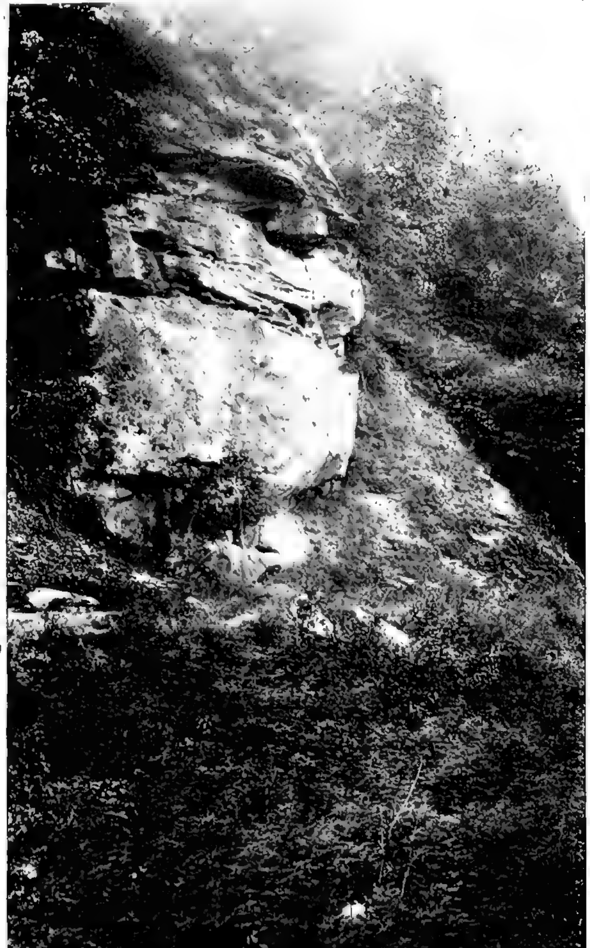
On the east fork of Grand River at Graham's Mill (NE. ¼ sec. 21, T. 58 N., R. 24 W.) and about one mile below, the top of the Henrietta outcrops a few feet above the water and one to two feet above is a thin seam of coal, probably the equivalent of the Mulberry coal of Bates County. The hills for two miles south of Graham's Mill contain a limestone (Altamont?) 2 to 6 feet thick and about 70 feet above the base of the Pleasanton. This limestone is absent, however, in Broadhead's section at the mill, which is as follows:

SECTION AT GRAHAM'S MILL, LIVINGSTON COUNTY.

Number.	Stratum.	Thickness. Ft.	in.
1	Slope, with sand, clay and pebbles of drift	23	
2	Sandstone, thinly-stratified, micaceous, and shale; some beds have carbonaceous partings	113	
3	Shale, bituminous	1	2
4	Shale, blue		8
5	Shale, sandy and clay, with occasional ochery stains and concretions of iron pyrites	5	6
6	Shale, semi-bituminous; thin laminae with Cordaites and carbonaceous stains		4
7	Coal, good bituminous (Mulberry)		10½
8	Clay (base of Pleasanton)	1	
9	Limestone, drab, roughly bedded; fossiliferous	5	10
10	Limestone, shaly, fossiliferous		6
11	Shale, pyritiferous		7
12	Shale, blue	4	

At the Cox mines, northwest of Chillicothe (sec. 11, T. 58 N., R. 24 W.), the Mulberry(?) coal is overlain by 43 feet of shale under 10 feet of sandstone, but a short distance north the thin-bedded sandstone and shale of the Pleasanton is replaced by heavy-bedded sandstone and near the south line of section 2 of this township, in the bed of Grand River, there is a conglomerate containing many fragments of limestone. At Gillaspie's Mill (SE. ¼ sec. 27, T. 59 N., R. 24 W.) the upper 86 feet of the Pleasanton is sandstone. Over all the area just discussed the Ovid coal horizon is marked by a thin coal seam or black shale at the top of the Pleasanton.

Northwest of Wheeling, on Medicine Creek, the Pleasanton outcrops in a small area. A section up the west bank of the creek near the old mill in section 14, T. 58 N., R. 23 W., shows:



Pleasanton sandstone at Big Bluff, near Trenton, Grundy County.

SECTION NORTHWEST OF WHEELING.

Number.	Stratum.	Thickness.
		Feet.
1	Sandstone	21
2	Slope, covered	38
3	Shale, drab	10
4	Limestone, blue, blocky, shaly at top (Altamont?)	2
5	Shale, drab	16
6	Coal, poor	⅓
7	Shale, drab, to water	10

The distance from the base of this section to the base of the Pleasanton could not be ascertained, but a short distance southeast (northeast corner section 23) the Mulberry(?) coal has been mined.

Linn County.—On the ridges near Linneus and Bucklin the lower portion of the Pleasanton is represented by 20 feet or more of red and green argillaceous shale like that in Carroll County. In the northwestern part of Linn County the formation is thicker and includes the upper sandy portion. This is discussed more fully under Sullivan County.

Grundy County.—All of the Pleasanton outcrops in this county and is about 140 feet thick. The chief outcrops are near Spickard, Trenton, Brimson, and Laredo, sandstone being the most conspicuous constituent. At one place the base of the mound in the NW. ¼ sec. 32, T. 62 N., R. 25 W., red shale similar to that in Linn County is exposed. In the central and southeastern portions of the county the Pleasanton unconformity is well marked, the lower part of the Pleasanton and all or a part of the Henrietta having been removed prior to the deposition of the sandstone, sandy shale, and coal of the upper part of the Pleasanton.

Drilling in Trenton shows none of the Henrietta or upper limestones of the Cherokee, the Pleasanton resting directly on the Cherokee. At the Main Street bridge over Grand River the unconformity is plainly exposed, with a layer of conglomerate resting on the various beds of the Henrietta.

Along Medicine Creek and south of Laredo, sandstone belonging to the Pleasanton formation is underlain by a thin coal bed which rests on the Henrietta. The following section was measured west of the railroad in the SW. ¼ sec. 23, T. 60 N., R. 23 W.:

SECTION OF PLEASANTON FORMATION SOUTH OF LAREDO.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Sandstone, brown, varying from thin-bedded to massive, cross-bedded	20	
2	Shale, black, "slaty," with large lenticular concretions	2	6
3	Coal (Mulberry)		3–4
4	Clay, with streak of coal at top, shaly below	5	6
5	Limestone (top of Henrietta)	—	—

Sullivan County.—On Locust Creek the Pleasanton extends south to near Purdin and there is coal at the base in the SW. ¼ sec. 10, T. 59 N., R. 21 W. The sandy phase appears west of Browning, as shown in the following section (NE. ¼ NW. ¼, sec. 7, T. 60 N., R. 20 W.).

SECTION NEAR BROWNING.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Slope to top of hill	21	
2	Sandstone, brown, quarried at one time, no definite outcrop, but covers hillside for a vertical distance of	21	
3	Slope, covered	26	
4	Limestone, drab to gray; coarse-grained; concretionary	1±	
5	Shale; drab and argillaceous at top; slaty below	5	4
6	Coal (Mulberry?)		7–8
7	Clay		3 +

About five miles north, on the west side of middle Locust Creek (sec. 7, T. 61 N., R. 20 W.), the following was seen:

SECTION SOUTHWEST OF CORA.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone (Hertha)	4	6
2	Slope with outcrop of coal (Ovid)	7	
3	Shale; arenaceous at top; drab and argillaceous below	75	
4	Limestone, blue; even layer		8
5	Shale, dark; contains many fossils		7
6	Limestone, dark argillaceous		3
7	Shale, dark		3
8	Limestone, dark argillaceous		3
9	Shale, blue; becoming darker at base, with a small pocket of coal near base	6	
10	Concealed	33	4
11	Shale, buff to drab, with small calcareous concretions (part of Labette shale)	12	

The horizon of the Pawnee limestone is about 13 feet above the base of this section, so that the Pleasanton is about 120 feet thick. Nos. 4 to 8 of this section outcrop on Spring Creek in northeastern Sullivan County and on middle Locust in sections 16 and 30, T. 63 N., R. 20 W., where they may be recognized by their striking molluscan fauna (the *Trepospira sphaerulata* zone). It is possible also that they may represent the limestone in the Pleasanton northwest of Wheeling and near Youngstown. North of this place, on middle Locust, Broadhead gives sections showing 60 to 88 feet of sandstone. At one place northwest of Milan (Blaylock's bridge) he found the following:

SECTION AT BLAYLOCK'S BRIDGE, NORTHWEST OF MILAN.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Sandstone	60	
2	Shale, bituminous	1	6
3	Coal, slaty	1	
4	Shale	18	
5	Shale, bituminous	2	6
6	Coal		6
7	Shale and limestone nodules	5	
8	Limestone	1	6
9	Limestone, shaly	1	6

At another place, west of Milan, south of the road up the west side of the creek (sec. 19, T. 62 N., R. 20 W.), the following was measured:

SECTION TWO MILES WEST OF MILAN.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Shale, drab, sandy	—	—
2	Shale, black, slaty, with lens-shaped calcareous concretions	1	6
3	Clay, light gray, nearly white	3	
4	Coal (Mulberry?)		6
5	Clay	2	
6	Limestone (Pawnee)	—	—

On the road 11 feet of red shale are exposed above the Pawnee. Three miles northwest of Milan the Ovid coal, 14 inches thick, is exposed about 30 feet below the top of the Pleasanton. At Boynton, a few miles north, the following section was made one-fourth mile northwest of the depot:

SECTION NEAR BOYNTON.

Number	Stratum.	Thickness. Ft.	in.
1	Sandstone; massive to thin bedded; cross-bedded	40	
2	Conglomerate, gray; composed of quartzite and other pebbles, with silicious (?) cement; surface honeycombed where weathered; 17 inches to	2	7
3	Shale, gray, arenaceous, micaceous	5	

A short distance north, only sandstone can be seen above the water in East Locust Creek.

Near the head of West Yellow Creek (sec. 11, T. 63 N., R. 19 W.), there are outcrops of yellow, micaceous sandstone and blue, sandy shale, the maximum thickness seen being 25 feet. North of Green City, on a branch in sec. 4, T. 63 N., R. 18 W. and sec. 34, T. 64 N., R. 18 W., is an outcrop which may be taken as representative of the Pleasanton of northeastern Sullivan County.

PLEASANTON FORMATION NORTH OF GREEN CITY.

Number.	Stratum.	Thickness. Ft.	in.	Distance from top. Ft.	in.
1	Clay, red and yellow		6		6
2	Coal (Ovid)		2		8
3	Shale; at top brown and black; slaty, with concretions; a sandy shale below	1	6	2	2
4	Sandstone, gray to yellow, calcareous, thickness varies from 14 inches to	3		5	2
5	Sandstone; yellow at top, grading down through blue, sandy, micaceous to non-micaceous shale	57		62	2
6	Shale, dark calcareous, pyritiferous, fossiliferous } Altamont?		6	62	8
7	Limestone, blue, fossiliferous, subcrystalline } Altamont?		8	63	4
8	Shale; upper foot clayey, passing into two feet of shaly sandstone, then greenish, arenaceous, micaceous shale	12		75	4
9	Shale, red, argillaceous	6		81	4
10	Interval to base of Pleasanton about	2	6	83	10

The Ovid coal, which is ten to twenty feet below the top of the Pleasanton, varies from a streak to 2 feet, though its horizon is usually marked by black, slaty shale, 2 to 7 feet thick. Although overlain by slaty shale in nearly all outcrops, the material beneath the coal may be slaty shale, clay, or sandstone. In many if not all outcrops the Pleasanton has near the top a calcareous and cross-bedded layer, which, however, is absent where the underlying sandstone is thin. In places sandy shale takes the place of the sandstone.

Putnam, Schuyler, and Adair counties.—South of Rosewood, in Putnam County, the Pleasanton has at the base a layer of coarse-grained sandstone and conglomerate with a maximum thickness of 20 feet. At this place it is high above Spring Creek, but near Mapleton on Dog Branch, and across Chariton River on Elm Creek in Schuyler County, a conglomerate closely resembling it outcrops at a much lower level and rests on beds of Cherokee age.

It is probable that this is an equivalent of the Chariton conglomerate of Bain in Appanoose County, Iowa.[1]

The limestone (No. 7 of last section) is persistent throughout this area, but its distance above the base of the Pleasanton is variable. It is very probable that it is to be correlated with the uppermost member of Bain's "Appanoose formation." Below this limestone the Pleasanton contains more or less sandy shale, beneath which is a thin lenticular coal seam overlain by black slaty shale and with a layer of red shale a short distance below it.

The Pleasanton formation extends into Adair County, south of the Quincy, Omaha, and Kansas City railroad, though its exact areal distribution is problematical. It does not extend to Kirksville, but along Chariton River it reaches to the latitude of Millard and has been seen as far southwest as the middle of T. 62 N., R. 17 W. The most complete section seen is that southeast of Youngstown (NE. ¼ NE¼, sec. 27, T. 62 N., R. 16 W.):

PLEASANTON FORMATION SOUTHEAST OF YOUNGSTOWN.

Number.	Stratum.	Thickness.		Distance from top.	
		Ft.	*in.*	*Ft.*	*in.*
1	Limestone (Hertha)	—		—	
2	Concealed (top of Pleasanton), about	25		25	
3	Shale, black	3		28	
4	Coal (Ovid); reported thickness	2	6	30	6
5	Concealed	10		40	6
6	Sandstone	42		82	6
7	Shale, black	1		83	6
8	Shale, red at base	35		118	6
9	Limestone (top of Henrietta)	—		—	

[1]Bain, H. F., Iowa Geol. Survey, vol. 5, pp. 394-398, 1895.

Due east of Youngstown, on the road east of the Chariton, the following is exposed:

SECTION EAST OF YOUNGSTOWN.

Number.	Stratum.	Thickness.	
		Ft.	in.
1	Glacial drift to top of hill	16	
2	Sandstone; at top brown or yellow and massive; shaly below	59	
3	Shale; brown; containing coal in places	2	
4	Shale; argillaceous; drab to purple	19	
5	Sandstone, buff, micaceous		8
6	Shale, argillaceous; white and green with red streaks and ferruginous concretions	21	
7	Limestone (top of Henrietta)	—	—

No. 3 of this section is correlated with No. 7 of the section just preceding and is probably the equivalent of the coal below the Altamont(?) limestone of Sullivan and Livingston counties. A limestone in the Pleasanton of Adair County is shown in the following section near the two just given (east side sections 23 and 26, T. 62 N., R. 16 W.):

SECTION SOUTHEAST OF YOUNGSTOWN.

Number.	Stratum.	Thickness.
		Feet.
1	Sandstone, yellow; thin-bedded and cross-bedded at top	35
2	Limestone, gray, arenaceous, blocky (Altamont?)	4
3	Sandstone, shaly, and sandy shale	15
4	Shale, black; a few inches	—
5	Shale, argillaceous; red, green, and white	45
6	Limestone (top of Henrietta)	—

The limestone, No. 2, is also exposed in the gully south of the road in sec. 26, but farther west, down the hollow, it is absent and its place taken by 10 or 15 feet of conglomerate (Chariton? conglomerate of Bain) which grades up into the sandstone, No. 1.

West of Chariton River, in the SE. ¼ SW. ¼ sec. 36, T. 63 N., R. 17 W., the Pleasanton is exposed near water level on Billy's Creek, where it rests on the Cherokee shale, apparently near the Lexington coal horizon. The section here is as follows:

SECTION SOUTHWEST OF NOVINGER.

Number.	Stratum.	Thickness. Ft.	in.
1	Sandstone, more than	10	
2	Shale, drab	3	
3	Shale, black, slaty; containing large lens-shaped concretions; averages	3	
4	Clay, gray		2-12
5	Coal		2-12
6	Clay, to water	3	

The Pleasanton is exposed in the eastern part of Putnam County and is usually represented by a few feet of shale. Near South Blackbird Creek, opposite the northeastern corner of Sullivan County, it contains, however, a considerable thickness of the sandstone and some conglomerate that is probably the same as the Chariton conglomerate of Bain in Iowa. The Pleasanton here rests unconformably on beds of Henrietta or Cherokee age. In a few places the *Trepospira sphaerulata* zone was found 20 to 30 feet above the base of the formation. A few feet of reddish shale in the northwestern corner of Schuyler County represent the Pleasanton in that county.

Harrison and Mercer counties.—There are many outcrops of the Pleasanton on both forks of Grand River drainage north of Trenton, but none that show all of the formation. The thickness indicated by drilling near Princeton is about 160 feet. The Ovid coal outcrops near the top of the Pleasanton throughout this region or its horizon is marked by black shale below which is one or two feet of impure limestone or calcareous sandstone. The remainder of the Pleasanton exposed is sandstone and shale, largely the former. Drillings show a widespread unconformity within the Pleasanton in both counties and at one place north of Princeton the total thickness of the formation is only 43 feet. West of Mercer, on Grand River, the *Trepospira sphaerulata* zone was found.

Howard County.—Stretching from west of Fayette to north of Roanoke is an outlier of Pleasanton containing red and drab shale, sandy shale, and sandstone, closely resembling the Pleasanton at its nearest outcrop on the west. The best exposure is near Roanoke where a maximum thickness of about 30 feet outcrops.

Platte and Clay counties.—In a drill record from near Kearney[1] the Pleasanton is reported 112 feet thick, over half of it being sandstone. At Smithville it is reported 110 and 119 feet, respectively, in two drillings; in one as shale and in the other with a five-foot limestone near the middle. The thicknesses given are less than those in outcrops on the east and more accurate records on the west. In western Platte County and at Leavenworth, Kans., the reported thickness varies from 155 to 173 feet, most of which is shale. In the Lansing shaft two inches of coal (Mulberry?) were found nine feet above the base. In one of the shafts at Leavenworth the lower part, 68 feet thick, is sandy shale. Near Kansas City, Kans., the total thickness was found to be 181 feet, the greater part being shale.

Buchanan and Clinton counties.—The nature of the Pleasanton in Buchanan County is well shown in the logs of core drillings at Saxton, Mo., and Atchison, Kans. The thickness in the former is 128 feet and in the latter 129½. The thickness at Lathrop, 117 feet, agrees with these, though sandy shale and sandstone are the chief constituents. At Cameron, north of Lathrop, the Pleasanton is probably 162 feet thick, nearly all of it being shale, largely of a red color in the lower part. The Ovid coal was found in nearly all drillings in the county.

Other northwestern counties.—The Pleasanton drillings in this territory show a number of beds of limestone, so that in places the delineation of its boundary is impossible. At Forest City (see page 215), the lower boundary cannot be exactly determined. At Maryville, a layer of limestone 118 feet below the top of the Pleasanton makes it uncertain whether a thickness of 118 or 151 feet should be assigned this formation. Drillings in southwestern Iowa at Bedford[2] and Clarinda[3] indicate a thickness of 145 and 142 feet, respectively, for the Pleasanton.

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[1]Shepard, E. M., Underground waters of Missouri: U. S. Geol. Survey Water-Supply Paper 195, p. 60, 1897.

[2]Norton, W. H., and others, Underground water resources of Iowa: U. S. Geol. Survey Water-Supply Paper 293, pp. 963-963, 1912.

[3]Smith, Geo. L., Carboniferous section of southwestern Iowa: Iowa Geol. Survey, vol. 19, pp. 618-620, 1909.

CHAPTER III.

CHANNEL SANDSTONE DEPOSITS.

THE CHANNEL DEPOSITS KNOWN AS THE WARRENSBURG AND MOBERLY SANDSTONES.

CHARACTERISTICS AND AGE.

Among the most unique features of the Missouri Pennsylvanian are two long, narrow channels filled with sandstone and shale which have been eroded in Cherokee, Henrietta, and some Pleasanton strata in Johnson, Lafayette, Randolph, and other counties (see State map in pocket). Remnants of other channels have also been found in many parts of the Pennsyvanian area and many more probably remain to be discovered as the net of detailed geologic work is spread over the State.

The channels are of great scientific interest, for they must have been formed during an interval of more or less widespread emergence and erosion during Pennsylvanian time. If, as suspected, the channel deposits are contemporaneous with certain sandstones and conglomerates of late Pleasanton age in north-central Missouri, this erosion interval occurred before the beginning of the Missouri epoch. The channels are also of considerable economic importance, for they removed in places valuable coal beds and in others have caused the substitution of excellent building stones for comparatively unimportant beds.

Swallow, Broadhead, and other early investigators in the State failed to recognize the significance of the channel deposits and considered them regularly inter-stratified with "Lower Coal Measure" beds. Winslow, however, realized their true relationships,[1] and was followed by Marbut[2]. These writers

[1]Winslow, Arthur, The coal beds of Lafayette County: Missouri Geol. Survey Bulletin No. 1, p. 18, 1890. Preliminary report on coal: Missouri Geol. Survey, p. 24 et al., 1891. The Higginsville Sheet, p. 8 et al., 1892, and also vol. 9, p. 45, 1896.

[2]Marbut, C. F., Geological descriptions of the Calhoun, Lexington, Richmond and Huntsville sheets: Missouri Geol. Survey, vol. 12, pt. 2, pp. 123, 210, 270, 331, et al., 1898.

named the western channel deposits the Warrensburg sandstone and the eastern the Moberly sandstone and described and mapped about half of each of them in detail. The present writers examined and mapped the remainder of the two larger channels in a reconnaissance way and found detached but similar deposits in other localities. The areal distribution of the main channels is shown on the State geologic map in the back of this volume.

In describing the thick sandstones and sandy shales near Dover, Higginsville, and elsewhere in the Higginsville quadrangle, Lafayette County, Winslow advanced the theory that they are of fluvial or lacustrine origin and fill a channel eroded in the adjacent regularly deposited strata during a temporary emergence. As his principal reasons for this conclusion he gives:

1. The great thickness of the deposit.
2. Its long and narrow shape.
3. The superposition of the sandstone upon the "Middle Coal Measure" rocks.
4. The inclusion of fragments of adjacent rocks.

Subsequent work has fully confirmed Winslow's theory and shown that it is applicable to all parts of the Warrensburg and Moberly areas, though postulation of a lacustrine origin is hardly tenable. Perhaps the most striking feature of the channels is their great depth and length in proportion to their width. These old valleys must have been very steep-sided in many places. The length of the main body of the Moberly channel as now exposed is nearly 40 miles and of the Warrensburg more than 50, while their original lengths must have been much greater. The thickest part of the deposits is probably about 200 feet, possibly 370 at Higginsville, but the average width is not more than two or three miles. Because of their valley-shaped cross-section, concave upward, they are wider at the top than the bottom, and the highest and widest parts have been removed. It is believed, however, that the valleys were never appreciably wider and that during their excavation there was an abrupt descent into them from surrounding level plains.

The most conspicuous and probably also the most abundant constituent now filling these old valleys is sandstone, though there is much shale, some conglomerate, and a trifling amount of coal. The sandstones are brown, red, or gray and are micaceous. Some are firm and massive and in part cross-bedded; others are thin-bedded and rather poorly consolidated. The shales are blue and drab, and commonly sandy. In places, as at the Moberly clay pit, shales have filled most of the channel. The only coal found in the channels themselves is in thin films and streaks or in small chunks derived from neighboring ledges, but there are some small basins of thicker coal in deposits evidently connected with channel fillings near Armstrong and elsewhere. Pieces of silicified wood and large petrified stumps are common. There are fossil stems and other plant remains in many of the sandstones, and ferns in some of the shales. The most significant constituents are the conglomerates which lie at or near the base of the channels, either interbedded with or overlain by coarse sandstone. The pebbles are both rounded and angular and consist mainly of limestone in a very firm and compact calcareous matrix. They are several inches in diameter; so large that they could have been moved only by water in active motion. Many pebbles can be recognized as derived from the limestones of the Henrietta or other Pennsylvanian ledges. The conglomerates are commonly less than 10 feet thick, but occur in both the two main channels and in isolated deposits.

It is believed that the Warrensburg channel was made by water flowing from higher country on the Ozark dome, bringing with it sands and muds derived largely from early Pennsylvanian sediments. The Warrensburg stream was joined when it reached the present site of Missouri River by the Moberly River descending westward from an Ozark peninsula in northeastern Missouri, and the united streams continued northward or northwestward to the open sea. This condition did not last long, for the valleys have all the characteristics of a topography as youthful as that of the Red River of the North—deep trenches in level plains with very little lateral drainage. Shortly before the land was again submerged the channels were choked with sediment, swamps with thin peat beds were formed on the flood plains, until finally the sea again swept in and covered them.

The question of the age of the channels is an important and difficult one. They are evidently younger than the Cherokee, Henrietta, or lower part of the Pleasanton formations, as the valleys were excavated in all of these rocks after they were at least partially consolidated. They have not been seen to cross upper Pleasanton or higher strata. A large and very similar channel lies in the Lawrence shale at and near Waldron, Mo., and Leavenworth, Kans., but it apparently was not cut down lower than the Stanton limestone. If this channel was cut through the Hertha-Winterset escarpment and the thick limestone beds above it, as it would have been if it joined the Warrensburg and Moberly channels, it left no evidences that were noted during recent and former field investigations.

Fossil plants collected at Moberly and other places and examined by David White show that the channel deposits are certainly of Pennsylvanian age, but do not furnish sufficient evidence to establish their exact position within that series.

The presence of these channels undoubtedly indicates some period of general emergence and erosion. For several years evidence of this could not be found, although the heterogeneous character of the Pleasanton formation was recognized. In 1912 and 1913, however, detailed mapping in districts in which the contact of the Pleasanton and Henrietta was well-exposed, revealed a wide-spread unconformity within the Pleasanton in all of the north-central counties. Where regularly bedded the base of the Pleasanton is typically shaly, but the shales of some localities are replaced in neighboring areas by sandstones that are locally conglomeratic. The thickness of the Pleasanton is variable, not only in the north-central counties, but also in other parts of the State. In many places the otherwise persistent limestones of the Henrietta formation are absent, probably because they were removed by erosion and replaced by sandstones of upper Pleasanton age. The unconformity was accomplished without much warping, or by warping which was largely compensated by movements in the opposite direction when deposition was resumed, for the Henrietta formation below the Pleasanton is essentially parallel with the Kansas City formation above it.

The actual connection between the channel sandstones and those of the Pleasanton formation has not been and possibly can not be made owing to a lack of outcrops, but the writers feel justified in tentatively referring the channel deposits to the Pleasanton epoch.

Bain's Chariton conglomerate of Appanoose County, Iowa,[1] is evidently the same as that recently found in Schuyler and adjacent counties in Missouri. The Red Rock sandstone of Marion[2] and Jasper[3] counties, Iowa, lies in a channel 2½ to 3

[1]Bain, H. F., Geology of Appanoose County: Iowa Geol. Survey, vol. 5, pp. 394-398, 1896.

[2]Miller, B. L., Geology of Marion County: Iowa Geol. Survey, vol. 11, pp. 153-161, 1901.

[3]Williams, I. A., Geology of Jasper County: Iowa Geol. Survey, vol. 15, pp. 316-322, 1905.

miles wide that has been traced for 27 miles from Eagle Rock northeastward. This sandstone has a maximuum thickness of 100 feet and has all the characteristics of the Warrensburg and Moberly sandstones. Iowa investigators have assigned its origin to contemporaneous erosion, but Miller notes its similarity to the Warrensburg, and Williams, from a study of the cross-bedding, considers it to have been made by a current of water flowing in a definite direction. There are other similar channels in Guthrie, Boone, and other Iowa counties that may be contemporaneous with those in Missouri.

THE WARRENSBURG SANDSTONE.

The Warrensburg sandstone fills a channel about 50 miles long, extending from north of Lewis station, Henry County, northward to the north bluffs of Missouri River. The sandstone belt, as at present exposed, has an average width of two miles, but just south of the Missouri widens to six miles.

In northeastern Henry County there are several large sandstone areas that may or may not occupy a part of the Warrensburg channel. Directly west, south, and east of the end of the channel, as mapped, no sandstones that appeared to be channel deposits could be found, although it is very unlikely that the channel began or ended as abruptly as shown (see geologic map of State in pocket).

The Warrensburg sandstone is well exposed in the northwestern quarter of the Calhoun quadrangle (secs. 28 and 29, T. 43 N., R. 25 W.), where over 106 feet of it outcrop. In one place sandstone extends from 10 feet above the horizon of the Fort Scott limestone to at least 77 feet below it. In the vicinity of Sand Creek springs the basal conglomerate is exposed, declining in altitude southward. Near here Marbut[1] found 15 feet of conglomerate composed of limestone, shale, coal, and sandstone pebbles, and associated with thick beds of sandstone.

West of Post Oak (Lingo City), Johnson County, the top of the channel sandstone is on a level with the top of the Henrietta formation, but nothing is known of its depth. It contains rather large specimens of silicified wood. Between this and Warrensburg a number of wells that do not reach the bottom of the sandstone show it to be at least 90 feet thick.

At Warrensburg the channel is one to two miles wide and

[1]Marbut, C. F., Geological description of the Calhoun sheet: Missouri Geol. Survey, vol. 12, pt. 2, pp. 158-159, 1898.

at least 87 feet and possibly 175 feet deep. A drilling 2½ miles north of Warrensburg penetrated 75 feet of sandstone and 100 feet of soft dark sandy shale, the former a channel deposit and the latter of either Warrensburg or Cherokee age. The bottom of this drilling is at least 105 feet below the horizons of limestones of the Henrietta formation in neighboring counties.

A very complete description of the characters of the sandstone at the quarries north of Warrensburg has been given by Buckley and Buehler[1] and need not be repeated here. Suffice it to say that the sandstone quarried has a light-gray or gray-blue color, is cross-bedded in places, and contains films of carbonaceous material in the bedding planes and irregularly distributed fragments of coal. Microscopic examination showed it to consist chiefly of small roundish to sub-angular quartz grains in a calcareous and ferruginous cement, with subordinate amounts of calcite, mica, chlorite, iron oxide, bitumen, feldspar, and clay. It closely resembles the stone at White Rock, near Miami Station.

Several outcrops in the vicinity of Warrensburg show the valley-like shape of the bottom of the channel. Irregular deposits of coal have been found just below the sandstone, and in the bed of the branch in the NW. ¼ NW. ¼ sec. 26, T. 46 N., R. 26 W. there are two beds of limestone dipping at a high angle and overlain by arenaceous channel deposits.

North of Warrensburg the channel averages probably 1½ miles wide. It lies just east of Fayetteville, and in southern Lafayette County is deflected slightly eastward so as to underlie the town of Higginsville. A drill hole near the Higginsville depot passed through 68 feet of surface material and penetrated 120 feet of sandstone, the lower part said to be "saturated with asphaltum." Below this sandstone 162 feet of shale and 20 feet more of sandstone were found, the latter resting on Mississippian limestone. As at Warrensburg, it is questionable whether the material below the thick sandstone should be referred to a channel deposit or to the Cherokee shale. Other drillings show more sandstone, but the one quoted seems to be the most reliable. The sandstone extends to at least 150 feet below the horizon of the base of the Henrietta. Coal is mined on both sides of the channel and is cut off sharply where entries have been driven to the edge of the sandstone.

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[1]Buckley, E. R., and Buehler, H. A., The quarrying industry of Missouri: Missouri Bureau of Geology and Mines, vol. 2, 2d ser., pp. 272-277, 1904.

North of Higginsville the channel abruptly widens to more than six miles along the south bluffs of Missouri River, presumably exists below the alluvium of that stream, and is exposed in one small area east of Lakeview in the north bluffs.

The widening north of Higginsville seems to indicate that the stream which carved the Warrensburg channel flowed to the north. The evidence furnished by the cross-bedding was found to be unreliable and the present altitude of the channel's base also has little significence, since post-Pennsylvanian movements have undoubtedly altered it slightly. When the bottom of the channel is plotted with reference to some known horizon, such as the base of the Henrietta formation, conclusions may be drawn with more certainty. In northern Henry County the base of the sandstone in the lowest point yet found is at least 77 feet, at Warrensburg 105 feet, and at Higginsville 150 feet below the base of the Henrietta. The fall south of Warrensburg, according to these figures, is 1.4 feet per mile, and north of Warrensburg about 2 feet per mile, the apparent difference in gradient being due, possibly, to the greater amount of limestone through which the channel was cut at the southern end. The hypothesis of northward flow obtained from the data given above, rests on the very probable assumption that, at the time of the making of the channel, the beds through which it was excavated were horizontal or nearly so. Unfortunately, the available data are rather meager, so that it is impossible to state definitely that the lowest channel deposits yet found in the localities mentioned actually lie in the lowest part of the old valley and not on its lower slopes.

THE MOBERLY SANDSTONE.

The Moberly channel extends from south of Madison, in Monroe County, west to Chariton River south of Salisbury. Its length is nearly 40 miles and its average width less than 3 miles. The maximum depth shown in drill records is about 200 feet. Although not as long as the Warrensburg channel in actual connected outcrop, its original length may have been almost as great, for it has been eroded away at its eastern end, in company with the other Pennsylvanian formations that formerly covered the Mississippian rocks in eastern Monroe and neighboring counties on the east and north, and is lost in the flood plain deposits of Chariton and Missouri rivers at its western end.

On Milligan Creek, Monroe County, from above Harris Springs nearly to its junction with Elk Fork, are notable outcrops of reddish sandstone, filling the eastern end of the Moberly channel. A short distance above Harris Springs a conglomerate appears below the sandstone. East and southeast of Middle Grove, Mississippian strata outcrop rather high on the divides

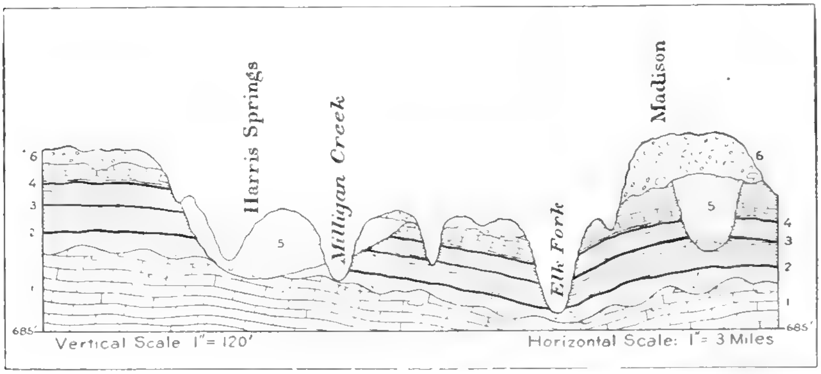

Fig. 4. Cross-section through Harris Springs and Madison. (1) Mississippian limestone. (2) Tebo coal. (3) Bevier coal. (4) Mulky coal. (5) Moberly channel. (6) Glacia drift.

and the Moberly sandstone has in greater part been removed by erosion. North of the village, however, sandstone rests on the Mississippian in low-lying outcrops and is the only indurated rock on the divides for over 3 miles. The total width of the channel in this vicinity is about 5 miles which is greater than noted elsewhere.

A tributary of the main channel from the northeast joins it near Evansville. This channel is about one mile wide and the sandstones filling it farther north and east are well exposed on Baker Branch, west of Madison, and on Pedee Branch at the edge of Madison. On the latter stream there are 4 feet of both angular and rounded pebbles of Pennsylvanian rocks firmly cemented in a calcareous matrix, with buff and red sandstone both above and below. At Madison the channel is bounded on the north and south by Cherokee strata with the cap-rock of the Mulky coal at the top, but its eastern continuation is concealed beneath drift on the divide between Madison and Holliday. It may be that some of the reddish sandstone seen west of Paris marks the direction taken by the upper part of the tributary. In a few places narrow channels were seen that were evidently small branches of the main lines of drainage.

Along the railroad and Coon Creek from Evansville nearly to Moberly are conspicuous red sandstones occupying the northern edge of the main Moberly channel. A short distance east of

Moberly there are exposed about 75 feet of massive red sandstone with intercalations of shale. The city itself is built over the main channel where it is 2 to 3 miles wide, as shown by numerous drillings that failed to find the Bevier coal, and by higher regularly stratified rocks that are exposed north of Kimberly, only a few miles northwest. In the large clay pit about one mile southwest of Moberly there are exposed:

SECTION IN CLAY PIT SOUTHWEST OF MOBERLY.

Number.	Stratum.	Thickness.
		Feet.
1	Shale, light-colored, sandy	12
2	Shale, dark-colored; carbonaceous; bears large rounded concretions of siderite and limestone and thin lenticular coal seams	20
3	Shale, drab, in thick layers	—

Plant remains, especially ferns, are plentiful, though comparatively few species are represented. Fossilized tree stumps are often dug out. It is reported that much more shale was found in a drilling made below this exposure. There were 50 feet of clay shale at another pit 1½ miles west of the city. The quantity of only moderately sandy clay shale in parts of the channel so close to thick sandstone beds is very surprising. The north side of the channel is different, however, for a shaft sunk one mile north of the Union railroad station penetrated 115 feet of sandstone below 85 feet of glacial drift. Below the bottom of the sandstone, which is at about 675 feet above sea level and 50 feet below the Bevier coal horizon, are two thin coal seams and some beds of clay and shale lying in the lower part of the Cherokee shale. In some of the mines near the Wabash railroad about 2 miles west of Moberly, the north edge of the sandstone was found replacing the Bevier coal bed and similar deposits probably reached lower depths a little farther south.

From a point about 2 miles southeast of Huntsville west to three miles beyond the Chariton County line the Moberly channel has been carefully examined and mapped by Marbut,[1] who showed conclusively that the phenomena can be accounted for only by the presence of a deep channel and not by any ir-

[1]Marbut, C. F., Geology of the Huntsville quadrangle: Missouri Geol. Survey, vol. 12, pt. 2, pp. 312-371, 1898. Map republished in revised form in vol. 11, 2d. series, Missouri Bureau of Geology and Mines, 1912.

regularity in the deposition of the Cherokee shale. In this area the outcrop of channel-filling sediments is two to three miles wide and of unknown depth in the middle, although it is certain that it extends to below the Bevier coal horizon. The deposits are chiefly coarse, thick-bedded sandstones, cross-bedded in many places and forming bluffs 50 feet or more in height. In some localities this sandstone may be seen truncating the regularly and horizontally bedded Cherokee strata. Where the base of the sandstone is exposed on the sides of the channel a rather thin but firmly cemented congolomerate commonly lies between it and Cherokee strata.

Although no tributaries have been traced directly into the main channel in the Huntsville quadrangle, there are many evidences that a considerable drainage system was developed some time after the deposition of the earliest Pleasanton sediments. Two and three miles southwest of Yates considerable sandstone is exposed and in the same locality (center sec. 29, T. 52 N., R. 15 W.), the "Chaetetes limestone," the bottom-rock of the Lexington coal horizon, is cut off sharply by sandstone that is strongly conglomeratic near the limestone (fig. 5).

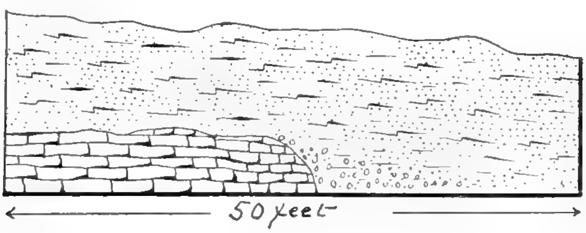

Fig. 5. Cross-section showing channel southwest of Yates, Randolph county (Marbut).

Two miles west of this (sec. 25, T. 52 N., R. 16 W.), two small mines were formerly operated in coal basins that lie near the base of a channel deposit. Near these mines there is also much sandstone and sandy shale that in some places rests on the bottom-rock of the Lexington coal, and in others on the Pawnee limestone, the top member of the Henrietta formation. All of these arenaceous outcrops southwest of Yates were evidently parts of one small channel that possibly also extended to a prospect shaft beside the railroad one mile southwest of Yates, but its connection with the main Moberly channel could not be traced. In the country northeast and southeast of Roanoke, however, there are many places where the Pawnee limestone and, more rarely, the Fort Scott are absent and their places taken by more or less sandy shale. The persistence of the limestones of the Henrietta formation in character and thickness in neighboring territory indicates that they were all originally deposited in this area also and were afterwards removed by erosion.

Shafts and drillings at Salisbury revealed 100 to 150 feet of sandstone and shale near the surface and no trace of the Bevier coal and other regular Cherokee strata that outcrop only two miles east of town and on Chariton River between Salisbury and Keytesville. Much massive, red, micaceous sandstone outcrops near Salisbury, and one mile south of town 30 feet of it overlie Cherokee strata that are near the Tebo coal horizon.

Near Rockford, on Chariton River about 3 miles southwest of Shannondale, there are excellent exposures of red, micaceous sandstone that fill either the main Moberly channel or one similar to it. In a narrow, steepsided valley near the store are high walls of this sandstone, some cross-bedded, some thin-bedded, but most of it massive. In one place (southeast corner sec. 34, T. 53 N., R. 18 W.) it may be seen resting on the upturned edges of two two-foot layers of dark-blue, fine-grained Pennsylvanian limestone that dip 30° to 60° south of east. A well on the upland near the head of the valley penetrated 110 feet of sandstone below 25 feet of surface material. Up the Chariton from Rockford to within two miles of Keytesville Station there are sandstone bluffs 75 feet or more in height, with regular Cherokee strata outcropping farther up stream.

In the region south of Salisbury the topographic relief is slight, the altitude low, and the rare outcrops much obscured by till and loess. The course of the Moberly channel across it is, therefore, doubtful. It seems likely that it was deflected to the north to Salisbury and then turned south to Rockford in a great bend, though it is possible that it continued its nearly straight westerly course from the boundaries of the Huntsville quadrangle across Middle Fork to Rockford and that a tributary from the north joined it by way of Salisbury. The drift is very thick east of the Rockford Moberly area and the absence of sandstone outcrops between it and the channel deposits just off the northwestern tip of Howard County could be accounted for by preglacial erosion.

There is no trace of the continuation of the Moberly channel between Chariton River and Miami Station, 20 miles west. This is not surprising, for the ancient river probably followed the present wide flood plain of Missouri River and all traces of it have been removed by erosion. If it touched the Saline County side of the river it would probably have been raised subsequently by the relative uplift to which part of that county has been subjected, and, in that case also, its deposits would have been subjected to vigorous erosion. Deposits at Brunswick may have filled only a tributary channel.

Along the bluffs from Miami Station to White Rock quarries, a little more than a mile southwest, the north side of a channel sandstone deposit is exposed, the rest of it having been removed during the excavation of the Missouri valley.

White Rock lies almost directly in line with the direction taken by most of the Moberly channel and is evidently part of what was a large deposit, indicating strongly that it was formerly connected with the Rockford channel on Chariton River. In the bluffs near Miami Station the sandstone is brownish-red and bears intercalated shale, but at the White Rock quarries there is a face of massive, light-gray sandstone composed chiefly of rounded, semi-translucent quartz grains in a calcareous cement. There are subordinate amounts of iron oxide, feldspar, and clay, abundant small flakes of white mica, and many carbonized plant remains along bedding planes. The maximum thickness of sandstone is said to be about 80 feet. At the north end of the quarry Cherokee strata appear beneath the sandstone, which disappears completely within a short distance.

From White Rock the Moberly channel probably continued its westerly course and joined the Warrensburg channel north of Dover, Lafayette County. The probable coincidence of the present Missouri River valley and the Moberly channel from Dover to Rockford is interesting. Although the channel deposits are more resistant than the Cherokee strata that in greater part are now adjacent to them, they are more easily eroded than the compact limestones of the Henrietta and Kansas City formations that formerly extended over this territory. During its early stages, therefore, the Missouri would find it easier to carve its way through the Moberly deposits than to attack the older formations and it may be that this part of the river had its course determined by that of the earlier stream that once occupied the Moberly channel.

OTHER CHANNEL DEPOSITS.

Outcrops of thick Pennsylvanian sandstone beds lying in more or less unconformable fashion on lower strata were found at many places within the State. Many of these are, of course, nothing more than regularly interbedded arenaceous deposits, but where material was found filling narrow, gorge-like valleys or containing well-defined conglomerates it is thought worthy of special mention.

Nearly due west of Hallsville, Boone County, on Silver Fork, there is a low bluff of sandstone at the horizon of the Summit coal and other rocks exposed only a quarter mile up stream. Traces of a similar channel were seen on Hinkson Creek drainage northeast of Columbia.

At Duncans Bridge, in the northwestern corner of Monroe County, and for a mile or more west and south, there is much red sandstone resting on Mississippian limestone in places and on Cherokee shale in others. Farther up Salt River more red sandstone outcrops and is particularly conspicuous in the neighborhood of Woodville, in the southeastern corner of Macon County. Near this village are 40 feet or more of massive, red sandstone and no sign of the Cherokee strata that outcrop within a mile. In several places there are beds of conglomerate near the base of the sandstone, containing limestone pebbles in a firm calcareous matrix. Most of the pebbles have all the characteristics of Pennsylvanian rocks, some bearing the coral Chaetetes and much resembling the highest calcareous bed of the Cherokee. Fossil ferns of Pennsylvanian age were gathered from shaly parts of the sandstone. The material was, therefore, laid down in Pennsylvanian time, but not until after the consolidation of at least some of the Cherokee strata. North of west from Woodville, on Hoover Creek (SE. ¼ sec. 28, T. 56 N., R. 13 W.), Cherokee beds at about the horizon of the Tebo coal are overlain with six feet of conglomeratic sandstone dipping 30° to the east. Sandy shales and sandstones are much in evidence in the vicinity.

A drilling at Cairo, Randolph County, penetrated 23 feet of sandstone under 33 feet of surface material, but its relationships are not certain, nor are those of the sandstone that replaces the limestone cap-rock of the Mulky coal two miles southwest of town (center sec. 3). A mile and a half southwest of Macon

City (by-road, NW. ¼ SW. ¼ sec. 20), a small outcrop shows sandstone replacing the cap-rock of the Summit coal in a similar manner.

A few miles southeast of Laclede, at Woodland Mills (near center of sec. 14, T. 57 N., R. 21 W.) there is an outcrop of sandstone that is in part conglomeratic at the base. This deposit overlies shale and limestone of the Des Moines group, but it was impossible to determine whether it is a channel deposit of the Warrensburg type or has been faulted into its present position. A few hundred yards southeast there are other beds of limestone and sandstone dipping at an angle of 80°. Considerable reddish sandstone outcrops in neighboring territory.

In the territory northwest of Woodland Mills there are several localities in which sandstones of the Pleasanton formation have peculiar relationships. Near Wheeling, Livingston County, sandstones which at one place (sec. 31, T. 58 N., R. 22 W.) are apparently resting uncomformably on the Fort Scott limestone, were found at another about three miles northwest underlying and involved in folding with limestones of the Missouri group, showing conclusively the Pleasanton age of these particular sandstones. Still farther northwest (sec. 2, T. 58 N., R. 24 W.) conglomerate, similar to that accompanying the Moberly sandstone, was found in the bed of Grand River, and sandstone known to be of Pleasanton age has a thickness of more than 86 feet. At Laredo, Trenton, and Melbourne are massively bedded sandstones of Pleasanton age. Drillings at Trenton indicate that the whole of the Henrietta formation was removed before the deposition of the sandstone. Near Mill Grove and Princeton there are thick sandstone deposits of the Pleasanton formation. In one place near Princeton (sec. 4, T. 65 N., R. 24 W.) the sandstone contains many coal streaks and fossil logs, one of the latter being more than six feet long and a foot in diameter. Drillings at Lineville that certainly started above the level of the Henrietta formation in neighboring territory show only sandstone and shale, either because of exceptional dips in that district or because the Henrietta beds have been replaced by deposits of Pleasanton age. At Mercer, Princeton, and Cainesville most or all of the Henrietta has been replaced by Pleasanton.

Another area where the Pleasanton possesses many of the characters of channel deposits stretches from Boynton, Sullivan County, to near Millard, Adair County. A conglomerate is exposed at the base of the formation near Youngstown, Adair County, south of Rosewood on south Blackbird Creek, west of

Fig. A. Warrensburg channel sandstone near Warrensburg.

Fig. B. Exposure at Woodland Mills, Linn County.

Mapleton on Dog Branch, Putnam County, and west of Queen City, Schuyler County. The maximum thickness of the conglomerate in this area is 20 feet, which, however, includes interbedded layers of coarse sandstone. Its correlation with Bain's Chariton conglomerate has been suggested in the discussion of the Pleasanton formation. This conglomerate is especially significant as, in township 65 north, each successive outcrop to the east is at a lower altitude and rests on older beds than its neighbor on the west, indicating an eastward slope of the surface on which it was deposited. It contains large rounded fragments of *Chaetetes milleporaceous*, not known to be in place nearer than 50 or 60 miles to the south.

A drilling near Millard, Adair County[1], penetrated no limestone at the Henrietta horizon, although the level at which the drilling began is higher than that of the nearest outcrops of that formation. Outcrops southwest of Novinger contain sandstone, probably of Pleasanton age, resting on beds of Cherokee age.

A number of peculiar occurrences of sandstone were noted in Chariton County and some have already been mentioned as connected with the Moberly channel. There is considerable difficulty in definitely placing many of these stratigraphically for some are certainly channel deposits and others may be of the age of the sandstone between the Mulky and Bevier coal beds that is so prominent in the Grand River bluffs east of Hale. One-half mile southeast of Rothville Station (center sec. 28, T. 56 N., R. 19 W.) and two miles east (W. ½ sec. 23) there is much sandstone apparently occupying the stratigraphic position of the Mulky coal and associated shales and sandstones of the Cherokee exposed in the bluffs one mile east of the depot. In several drillings near Indian Springs (Indian Grove) a surprising thickness of sandstone and shale with no coal or limestone is reported, while there are many sandstone outcrops in territory south of the village. Material of undoubted Moberly type was found four miles northwest of Brunswick, on Salt Creek (S. line sec. 20, T. 54 N., R. 20 W.), where sandstone that is 25 feet thick in neighboring outcrops, overlies horizontally a number ber of Cherokee strata dipping S. 30° E. at an angle of about 10°.

At the mouth of Hurricane Creek, one mile south of Glasgow, Howard County, there are 60 feet of sandstone, in greater part massive, and some sandy shale. This may possibly be a channel

[1]Hinds, Henry, The coal deposits of Missouri: Missouri Bureau of Geology and Mines, vol. 11, 2d ser., p. 55, 1912.

deposit, though the presence of pronounced folding and a heavy loess mantle in the area makes this difficult to determine, and Broadhead[1] may be correct in assigning to it a position among regular Cherokee strata.

In Lawrence, Christian, Greene, and Dade counties there are some sandstone deposits whose narrow, channel-like form has suggested their correlation with the Warrensburg sandstone. The position of the channel is such that it might be a continuation of the Warrensburg, a fact which added strength to the correlation. However, plants were found and identified by David White[2] as being much older than the Warrensburg. The sandstone in these channels is probably the same as that called Graydon Springs sandstone and conglomerate by Winslow, and Graydon sandstone by Shepard and other writers, which is believed to be of Cherokee age. It was apparently deposited in valleys eroded prior to the deposition of Pennsylvanian sediments. Two of these valleys have been traced for considerable distance and named,[3] "the Schoolcraft River, best seen at Graydon Springs, and the Swallow River, which has left a large bed of gravel, conglomerate, and sandstone a mile and a half east of Aurora. Both of these channels extend northward toward the Osage."

Sandstone and conglomerate, resting unconformably on upper beds of the Cherokee shale, cap the mound northwest of Walker, Vernon County (sec. 8, T. 36 N., R. 30 W.). The basal conglomerate contains boulders of Pennsylvanian limestone two feet in diameter, and the sandstone above, of which there is at least 25 feet, is brown, coarse-grained, and quartzose. The base of the sandstone is 12 to 20 feet above the Summit coal horizon, though the next mound on the north is capped by Henrietta beds and shows no such sandstone in the Cherokee shale below. It is to be presumed that the sandstone at Walker is post-Henrietta, but that it is of Warrensburg age or occupies part of the Warrensburg channel is uncertain.

A large channel very similar to the Warrensburg channel lies in the Lawrence shale member at and near Waldron, Mo., and East Leavenworth, Mo. It is described on pages 170 to 172.

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[1]Broadhead, G. C., (Geology of) Howard County: Missouri Geol. Survey, Report for 1873-1874, p. 187 et al., 1874.

[2]Personal communication.

[3]Babcock, E. N., and Minor, Jessie, The Graydon sandstone and its mineral waters: Bradley Geol. Field Station of Drury College, Bull. vol. 1, pt. 1, pp. 24, 1904.

CHAPTER IV.

MISSOURI GROUP.

GENERAL FEATURES.

The Missouri group is the upper or "barren" portion of the Pennsylvanian series in Missouri, the so-called "Upper Coal Measures" of early reports. It resembles the upper half of the Des Moines group lithologically, but differs from it as a whole in having more persistent strata, more limestone, less sandstone, and much less coal. The chief difference between it and the underlying Des Moines group, however, is faunal.

From an economic standpoint the group is not so important as the Des Moines. Small, local coal mines have been opened in Platte, Buchanan, Gentry, Nodaway, and Atchison counties[1]. The shales have been used for the various ceramic industries[2] and in making lime and Portland cement[3]; they contain an inexhaustible supply of material. The limestones are quarried[4] for crushed rock ballast and rough building stone and, in a few places, notably at Kansas City and Princeton, a small amount of dimension stone has been obtained. The sandstones have been used for flagging and rough building work, but most of them are too soft for such uses.

At the present time considerable interest is being taken in northern Missouri as a prospective oil and gas field and for this reason the structure is described in some detail in a separate chapter dealing with that subject.

AREAL DISTRIBUTION.

The Missouri group comprises the highest consolidated rocks in all of Missouri west of an irregular line extending from

[1]Hinds, Henry, Coal deposits: Missouri Bureau of Geology and Mines, vol. 11, 2d ser., 1912.

[2]Wheeler, H. A., Clay deposits: Missouri Geol. Survey, vol. 11, 1896.

[3]Buehler, H. A., The lime and cement resources of Missouri: Missouri Bureau of Geology and Mines, vol. 6, 2d ser., 1907.

[4]Buckley, E. R., and Buehler, H. A., The quarrying industry of Missouri: Missouri Bureau of Geology and Mines, vol. 2, 2d ser., 1904.

near Amsterdam, Bates County, to the northeastern corner of Mercer County (see Fig. 1). It also outcrops in a large territory in adjacent portions of Kansas, Iowa, and Nebraska. East of the main area, there are isolated outcrops in Bates, Cass, Johnson, Lafayette, Ray, Carroll, Livingston, Linn, Grundy, Sullivan, Adair, and Putnam Counties. The total area is about 8,000 square miles.

LITHOLOGIC CHARACTER.

Shale and sandstone strata constitute nearly three-fourths of the Missouri group, which is a series of alternating beds of shale, sandstone, and limestone, with a few thin beds of coal and clay. The limestones, being more resistant to the processes of weathering, are more prominent than the beds of shale and sandstone both in outcrop and in influence on the topography and have, therefore, produced an erroneous impression that the Missouri lithologically differs greatly from the Des Moines.

The following table shows the thickness of each kind of sediment in the group. It should be considered only an approximation obtained by taking the average thickness of each bed. The heavy sandstones which replace shale in certain areas are not included.

CHARACTER OF SEDIMENTS OF THE MISSOURI GROUP.

Kind of rock.	Thickness in feet.	Percent of total thickness.
Limestone	279	25.1
Shale, calcareous	17	1.5
Shale, argillaceous	577	52.0
Shale, sandy	158	14.2
Sandstone	63	5.6
Shale, bituminous	14	1.3
Coal	3	.3
	1,111	100.00

The lower part of the group, particularly the Kansas City formation, has a larger proportion of limestone, and is often reported as solid limestone by careless drillers. Bennett[1] has some interesting figures on the composition of the lower part of the group as exposed in the vicinity of Kansas City, Mo.

[1]Bennett, John, The Kansas City section: Kansas Univ. Geol. Survey, vol. 1, pp 30-53, 1896.

CHARACTER OF SEDIMENTS IN THE KANSAS CITY SECTION.

Kind of rock.	Thickness in feet.	Percent of total thickness.
Limestone	119	52.7
Limestone (thin layers in shale)	12	5.3
Shale, argillaceous and bituminous	94.6	42.0
	225.6	100.00

To the north the beds thin, particularly the shales. In northwestern Missouri and southwestern Iowa, drillings show very little sandstone in this group. The sandstones are usually arenaceous phases of strata which are elsewhere argillaceous. In Clay and Platte counties, and possibly in other areas, there are beds of sandstone comparable with those filling the Warrensburg and Moberly channels. The beds of coal and bituminous shale are closely associated with limestones as in the upper half of the Des Moines group. The coal beds are fairly persistent, though thin and widely separated stratigraphically, and have yielded little commercial fuel.

THICKNESS.

Broadhead estimated the thickness of the group to be 1,317 feet. This result was obtained by compiling a general section along Missouri River, a method which failed to show the thinning of the lower members to the north, where they are concealed by higher rocks. Drilling in the vicinity of the northwest corner of the State shows considerable thinning of all the shale and some of the limestone beds as compared with their thickness where they outcrop. The probable thickness of the Missouri group in Atchison County, where all formations are present, is close to 1,000 feet according to the Nebraska City drilling. This agrees approximately with Smith's estimate of 969 feet in southwestern Iowa[1]. That part of the Missouri group which is represented in Missouri has a thickness of 1,500 feet in southeastern Kansas.

[1]Smith, G. L., Carboniferous section of southwestern Iowa: Iowa Geol. Survey, vol. 19, p. 655, 1909.

SUBDIVISIONS.

From the great number of formation and member names proposed at various times the writer has selected, with the approval of Committee on Geologic Names of the U. S. Geological Survey, the following as being most suitable on the grounds of paleontology, lithology, or priority, as explained at the end of Chapter I.

FORMATIONS AND MEMBERS OF MISSOURI GROUP.

Formation.	Member.
Wabaunsee formation.	Undifferentiated shale and limestone. Tarkio limestone.
Shawnee formation.	Scranton shale. Howard limestone. Severy shale. Topeka limestone. Calhoun shale. Deer Creek limestone. Tecumseh shale. Lecompton limestone. Kanwaka shale.
Douglas formation.	Oread limestone. Lawrence shale with Amazonia limestone bed. Iatan limestone. Weston shale.
Lansing formation.	Stanton limestone. Vilas shale. Plattsburg limestone. Lane shale with Farley limestone bed.
Kansas City formation.	Iola limestone. Chanute shale with Raytown limestone bed and Cement City limestone bed. Drum limestone. Cherryvale shale. Winterset limestone. Galesburg shale. Bethany Falls limestone. Ladore shale. Hertha limestone.

GENERALIZED SECTION OF MISSOURI GROUP, AFTER BROADHEAD, THE FORMATION AND MEMBER NAMES BEING THOSE ADOPTED IN THIS REPORT.

	Broadhead's numbers.	Thickness.	
		Ft.	*in.*
Wabaunsee formation:			
Shale, red	3*a*	5	
Sandstone and shale; sandstone at top, upper three feet irregularly bedded and micaceous; green; below, 8 or 10 feet soft brown; then 35 feet shale and sandstone, red shales in upper part, thick-bedded sandstone at bottom	4	47	
Limestone, drab; weathers brown	5		10
Limestone, shaly; containing fossils	6	3	2
Limestone, blue, concretionary; traversed by calcspar veins	7	1	4
Shale, sandy or dark brown clay	8		2
Coal (Nyman) impure, and shales, 2-10 inches	9		2
Shale, ochery, sandy; thin streaks where coal is absent	10	—	—
Shale, sandy	11	22	
Tarkio limestone member:			
Limestone ,dark-blue, shaly	12	1	6
Shale, green and red, with nodules of limestone	13	1	6
Limestone, upper part nodular; weathers brown; abounds in Fusulina	14	4	
Shawnee formation:			
Scranton shale member:			
Shale, blue and drab; argillaceous	15	28	
Limestone, bluish-drab; fossiliferous	16	2	
Shale, blue; fossiliferous	17		10
Sandstone, hard	18	2	6
Sandstone, soft	19	3	
Sandstone, calcareous	20		10
Shale, blue, argillaceous; thickest where the sandstone above is absent	21	6–13	
Limestone, blue; tolerably fine-grained; perpendicularly jointed; weathers brown	22	1	
Shale	23	1	3
Limestone, buff, ochery; easily decomposed; jointed perpendicularly; fossiliferous	24		10
Shale, buff and olive	25	2	
Shale, red	26	2	
Shale, clayey and sandy with concretionary layers of sandy ironstone	27	30	
Limestone, shelly; fossiliferous; local	28	¼–1	
Shale, gray to black; local		¼–1	
Coal (Elmo); in places represented by black shale		¼–1	
Shale, drab		13	
Limestone, shelly, porous, ferruginous	224	2–4	
Shale; septaria occur near upper part	223	36	
Septaria 6 inches to 1 foot; fossiliferous	222	—	—
Shale	221	48	

*a*Numbers 3-28 are in the Atchison County section, numbers 224-74 in Missouri River section.

GENERALIZED SECTION OF MISSOURI GROUP—Continued.

	Broadhead's numbers.	Thickness.	
		Ft.	*in.*
Shawnee formation—Continued.			
Howard limestone member:			
Limestone, spathic; a 4-inch bed of carbonate of iron and lime at lower part; fossiliferous	220	2	
Shale, sandy	219	2	6
Limestone; 16 in. to 2 ft.; pyritiferous; very fossiliferous	218	1	6
Severy shale member:			
Limestone, arenaceous; not always present; composed mainly of ostracods	217	—	—
Shale, blue and black, slaty; in northern Nodaway County, black concretionary limestone occurs in the shales; both are fossiliferous	216	4	8
Coal (Nodaway); 4 to 16 inches; divided into different seams by 2 to 4 inches of blue clay	215		10
Sandstone and shales, containing plants	214	17	
Shale, argillaceous; fossiliferous	213	4	
Topeka limestone member:			
Limestone, deep-blue; compact; in thin layers with shale partings; fossiliferous; absent in places	212	¼–4	
Limestone, ash-blue; fossiliferous	211		6
Shale, brown, with nodular limestone layer; fossiliferous	210	4	
Limestone, dark ash-blue; fossiliferous	209		10
Shale, calcareous	208	1	
Shale, blue and black, slaty	207	1	6
Limestone, blue; resembles No. 209; fossiliferous	206	1	4
Shale, drab; in thick laminae	205	2	6
Shale, dark-green	204	1	4
Shale, green, nodular	203		8
Shale, yellow	202	1	4
Limestone, ash-blue or gray; coarse; sub-oolitic; weathers rough; fossiliferous	201		10
Shale; light-green passing into blue; has limestone concretions	200	2	6
Limestone ash-blue; rough; shelly; weathers brown; fossiliferous	199	2	6
Shale, blue	198	2	
Limestone, ash-blue or buff; weathers brown; fossiliferous	197	2	
Calhoun shale member:			
Shale, brown; fossiliferous	196	3	
Shale, sandy, and sandstone	195	4	
Shale, black and slaty; in places contains a thin coal seam	194	1	
Shale, sandy, micaceous	193	3	
Limestone, grayish-blue	192	1	9
Shale	191		5
Limestone, grayish-blue; highly fossiliferous	190		6
Shale, blue; in places 10 feet thick	189	3	6
Limestone, dull-blue; 4 to 10 inches; in places has a bed of cone-in-cone structure on upper surface; fossiliferous	188		10
Shale, 3 to 4 feet thick with Fusulina; fossiliferous	187	3	

GENERALIZED SECTION OF MISSOURI GROUP—Continued.

	Broad-head's numbers.	Thickness. Ft.	in.
Shawnee formation—Continued.			
Deer Creek limestone member:			
Limestone; ash-gray; fossiliferous	186	15	
Shale, blue and bituminous	185	5	
Limestone; even layer; fine grained	184	2	
Shale	183	7	
Limestone, buff	182	5	
Tecumseh shale member:			
Sandstone	181	2	
Shale	180[1]	2	
Shale, argillaceous or arenaceous	170	50	
Lecompton limestone member:			
Limestone, dark ash-blue; shelly; fossiliferous	169	2	
Shale, dark olive	168	3	
Limestone, light-drab, mottled with white specks; upper part nodular; lower part even; fossiliferous	167	3	
Limestone, shelly and nodular; fossiliferous	166	3	
Shale, dark	165	3	
Shale, black, slaty	164	1	
Shale, contains Fusulina	163		4
Limestone; contains Fusulina	162		10
Shale, yellow; contains calcareous nodules	161	9	
Limestone; light-brown; rough fracture; mottled with dark-brown streaks and white specks; fossiliferous	160	4	6
Kanwaka shale member:			
Shale, argillaceous	159	5	
Coal: local	158		½
Sandstone, shaly	157	9	
Coal; local	156		3
Shale, sandy	155	8	6
Limestone; contains Fusulina	154	2	
Shale	153	9	
Douglas formation:			
Oread limestone member:			
Limestone; 3 to 14 feet; strong, tough, silicious and oolitic; even layers; in places cross laminated; fossiliferous	152	9	
Shale; absent in a few places	151	3	
Limestone, grayish-drab; 27 to 35 feet; irregularly bedded; has a few cherty layers; very fossiliferous	150	27	
Shale	149	3	
Shale, blue and black, slaty	148	2	
Limestone, blue to gray; even bedded	147	2	4
Shale, blue	146	4	
Shale; like above	145	8	
Shale, whitish or blue	144	5	
Limestone, buff; fossiliferous	143	7	

[1]Numbers 171-179 of Broadhead's section are duplications of some of the next lower beds.

GENERALIZED SECTION OF MISSOURI GROUP—Continued.

	Broad-head's numbers.	Thickness. Ft.	in.
Douglas formation—Continued.			
Lawrence shale member:[1]			
Shale, white, red and green at top, variable below; contains locally 5 to 10 feet of sandy shale and sandstone (=Nos. 135 and 142), and 3 inches to 2 feet of coal which has many clay partings (=Nos. 134 and 141)	142–138	25–100	
Limestone (Amazonia bed); ferruginous; has a brecciated appearance where weathered	137	1–16	
Shale, drab; argillaceous (=Nos. 133 and 136)	127	56	
Shale, sandy, ferruginous, calcareous; highly fossiliferous (=No. 132)	126	2	6
Shale, drab to buff	125	6	
Limestone, drab, rough; locally calcareous sandstone	124		¼– 8
Shale, black, containing locally a thin coal seam	123		¼–10
Shale, gray, red, or green (=Nos. 129-130-131)	122	15–20	
Iatan limestone member:			
Limestone, gray, ferruginous; weathers to a brecciated appearance; at St. Joseph is 4-5 feet thick; attains maximum thickness near Iatan, Platte County (=No. 128); seemingly replaced sandstone in southern Platte County; absent in places	121	¼–22	
Weston shale member:			
Shale, drab, argillaceous; in places the upper part or whole of this shale is replaced by 50 feet or more of sandstone with a thin coal seam locally present near the base (=Nos. 116-119); the sandstone is seemingly unconformable at the base	120	60–100	
Lansing formation:			
Stanton limestone member:			
Limestone, sandy; fossiliferous	115	3	
Shale, blue or greenish; sandstone present in places	114	1-16	
Limestone, buff	113	3	6
Limestone, gray; fossiliferous	112	13	6
Shale, blue; middle 8 inches black and slaty	111	5	6
Limestone, blue; fossiliferous	110	4	
Vilas shale member:			
Shale; usually calcareous or bituminous where thin	109	4–19	
Plattsburg limestone member:			
Limestone, blue and gray, with buff shaly partings; fossiliferous	108	18	
Lane shale member:			
Limestone, shelly; in places arenaceous; fossiliferous	107	1	
Shale, blue and sandstone, buff, white or red	106-103	20–40	
Limestone, ferruginous, hard, conglomeratic; fossiliferous	102	1	
Shale	101	3	
Limestone (Farley bed), hard, ferruginous; 3 to 10 ft.; contains large fossils	100	3	
Shale, sandy	99	31	

[1] Broadhead's section of the Lawrence shale is much confused owing to certain duplications.

GENERALIZED SECTION OF MISSOURI GROUP—Continued.

	Broad-head's numbers.	Thickness.	
		Ft.	*in.*
Kansas City formation:			
Iola limestone member:			
Limestone, gray and buff; thin and irregularly bedded; fossiliferous	98	1–43	
Chanute shale member:			
Shale, blue; argillaceous; has ochery concretions; fossiliferous; contains sandstone and thin coal bed in places	97	5–30	
Limestone (Raytown bed), bluish-gray; contains large fossils	96	5	
Shale, blue and black, slaty	95	2	9
Shale	94		9
Shale, fossiliferous	93	1	1
Limestone, even bed; fossiliferous	92	1	1
Shale, blue, buff and reddish; in places sandy	91	5–15	
Limestone (Cement City bed), drab	90	9	
Shale, blue and olive	89	5	
Shale, buff and nodular	88	2	
Drum limestone member:			
Limestone, bluish-drab, irregularly bedded	87b	3	
Limestone, oolitic; very fossiliferous	87a	2–18	
Cherryvale shale member:			
Shale	86	15	
Limestone, blue; fossiliferous	85d	1	2
Shale, blue clayey	85c	2	6
Coal, poor; absent in places	85b		¼–4
Winterset limestone member:			
Limestone, very dark blue; silicious; with lenticular forms and concretionary beds of black chert; fossils numerous, especially in upper part	85a	8	8
Limestone, dove and drab colored; fine-grained; fossiliferous	84	9	4
Shale			5
Limestone, drab and blue; irregularly bedded; some chert concretions; has buff shaly partings; fossiliferous	83b	5	8
Shale, blue	83a		6
Limestone, blue; concretionary	82	1	
Galesburg shale member:			
Shale, blue	81c		11
Shale, black, slaty	81b	1	7
Shale, clay	81a	2	
Bethany Falls limestone member:			
Limestone, nodular and shelly; fine-grained	80	4	
Limestone, oolitic; attains a thickness of 8 feet in places; absent in others	79	¼–1	
Limestone, dun and gray; fossiliferous; varies from a thin-bedded to massive oolitic or "conglomeratic"	78	20	8
Ladore shale member:			
Shale, blue, argillaceous	77b	2	2
Shale, black, slaty	77a	1	4

GENERALIZED SECTION OF MISSOURI GROUP—Continued.

	Broad-head's numbers.	Thickness. Ft.	in.
Kansas City formation—Continued.			
Ladore shale member—Codtinued.			
Limestone, dull-blue; 14 to 18 inches thick; fossiliferous	76c	1	2
Shale, blue, argillaceous	76b		7
Limestone, concretionary; fossiliferous	76a		6
Shale, blue, argillaceous or sandy; contains sandstone in places	75	2–20	
Hertha limestone member:			
Limestone, gray and ferruginous; fossiliferous	74	4–18	

KANSAS CITY FORMATION.

CHARACTERISTICS.

At the base of the Missouri group is the Kansas City formation, essentially a lithologic and faunal unit. Beede and Rogers grouped the members of the formation into a single faunal series but divided it into three stages, making the Drum a separate stage from a study of the fauna of its oölitic phase at Kansas City. Girty also found the formation to be marked off from those above and below by certain faunal distinctions. At Kansas City over half the formation is limestone but to the north the amount of limestone decreases. Very little sandstone occurs in the formation, but thin beds have been found locally at three horizons. The shales are argillaceous or calcareous, but there are several persistent layers of black, slaty shale. The total thickness varies from 225 feet at Kansas City to about 200 feet in Harrison County. The type locality is at Kansas City, Mo. The outcrop is shown on the State geologic map.

MEMBERS.

Hertha limestone member.—The Hertha limestone is a resistant, heavy-bedded, gray, ferruginous, crystalline limestone, varying from 4 to 18½ feet in thickness, thinning to the northeast. South of Missouri River it is a rather massive, rough-appearing limestone. In northern Missouri it usually occurs in two beds, the upper about 2 feet and the lower 2½ feet thick, with shaly, sandy layers of impure limestone above and below. It weathers to a mottled or corrugated appearance which has led to its being called a "conglomeratic" or "fragmental" limestone. In other places it is thin-bedded with shaly partings. A few feet below its base there is usually a thin bed of coal (the Ovid seam).

Ladore shale member.—Above the Hertha is a shale member varying in thickness from 6 to 30 feet. In the upper part is a layer of slaty, carbonaceous shale underlain by a thin limestone commonly consisting of one or two layers. The remainder of the member is composed of shale and shaly limestone, or, where thicknesses approaching the maximum are attained, of sandstone and sandy shale. In Livingston County the sandstone is very firmly cemented.

Bethany Falls limestone member.—This member is composed of two beds, the upper of which is about three or four feet thick and made up of limestone nodules, that do not appear as a rule in natural outcrops but may be seen in quarries or railroad cuts. The lower bed is 12 to 21 feet thick and presents two distinct phases, that of a heavy-bedded, pitted or corrugated, unfossiliferous and somewhat loosely cemented limestone, as at the type locality, or of a thick-bedded oölitic rock. This phase weathers into thin beds and is rather fossiliferous. In places both types of limestone may be seen in the same face, in which case the latter is below the former. The general color is light or dark gray. It is locally known as the "Spotted-rock."

Galesburg shale member.—Between the Bethany Falls and Winterset limestones is a thin bed of shale, slaty in the middle and blue at the top and base. Its thickness in northern Missouri varies from 5 to 10 feet. In southwestern Missouri and southeastern Kansas the thickness is somewhat greater.

Winterset limestone member.—The Winterset is a blue, thin-bedded, limestone with buff shaly partings. Its thickness varies from 25 to 40 feet. At many places it is divided into three beds by thin shale partings. Throughout its outcrop, the Winterset is extremely cherty, a feature that has given it the local name "Chert ledge" at Kansas City, where the chert is dark-blue or nearly black and contains an abundant molluscan fauna. At Kansas City and east of Liberty, Clay County, the shale partings between the three beds are apparently thicker than usual. In the northern counties the top of the Winterset limestone contains many specimens of Fusulina.

Cherryvale shale member.—Above the Winterset limestone is an argillaceous or calcareous shale varying from 13 to 25 feet in thickness. Near the base is a thin layer of limestone (Broadhead's number 85d), that is persistent from Kansas City to northern Harrison County. Thin lenticular limestones occur in this shale in many places and, in the northern counties, a series of thin regular beds of limestone alternating with shale makes up most of the thickness. Blue or buff is the prevailing color, but in Jackson and Clay counties there is a layer of black shale, with a thin bed of impure coal in places.

Drum limestone member.—The next higher member is the Drum limestone. At Kansas City it varies from almost nothing to 18 feet thick, and is gray and oölitic. It thins to the northeast to 3 to 6 feet but usually retains its oölitic character. At Kansas City it is in places divided by a thin shale parting into two beds, the upper of which is known as the "Oölitic ledge" and the lower as the "Bull ledge." At Parkville and possibly at Liberty it is rather cherty.

Chanute shale member.—Above the Drum limestone is a composite shale member, the Chanute. At the base is a bed of shale 5 to 20 feet thick, in places calcareous but as a rule argillaceous and tinged with green, red or purple. Over it is a bed of gray, buff or cream colored limestone varying from 5 to 10 feet in thickness and here called the Cement City limestone bed, from the town of that name in Jackson County, Mo. At Kansas City it is known as the "Gray ledge" or "Building ledge." This is succeeded by another shale layer 10 to 15 feet thick and, like that below, tinged with red or purple in places. In this latter phase it is sometimes known as "Kimball" or "Madder dirt" to drillers. In other places a thin layer of persistent micaceous sandstone is found at this horizon. The upper part of this shale is the black "slaty" variety and is set off from the lower portion by a thin but persistent bed of limestone (Broadhead's number 92). Above the black shale is another bed of limestone, the Raytown limestone bed, 3 to 6 feet thick, gray and thinly bedded. To the north it becomes rather shaly in the middle. It is characterized by the large size of its fossils and is known among quarrymen at Kansas City as the "Calico ledge." At the top of the Chanute member is blue argillaceous shale, sandy shale or sandstone that varies from 5 to 30 feet in thickness. Where arenaceous a thin coal bed may occur. Where the upper layer of the Chanute shale is thin it is commonly the blue argillaceous phase.

Iola limestone member.—The upper member of the Kansas City formation is the Iola limestone. It is a light gray, somewhat crystalline, and thinly bedded limestone whose shaly partings weather to buff. At Kansas City where it is known as the "Crusher ledge" its maximum thickness is 43 feet but to the north, along its eastern outcrop it thins to nothing. In northwestern Missouri, west of its outcrop, drillings indicate that it is present but thinner than at Kansas City. The lower portion is usually a single layer about one foot thick, darker than the remainder and separated from it by a thin shale parting. It is persistent farther to the north than the upper portion and is overlain by a few inches of shale and a foot of loosely cemented material, largely made up of fossils. This shaly material is believed to be the equivalent of the upper part of the member.

REGIONAL VARIATION AND DETAILED SECTIONS.

Bates County.—As there has been some confusion in the correlation of the three lower limestones of the Kansas City formation, it is thought best to give Bennett's[1] section along Marmaton River near Uniontown, Kans., 22 miles west of the Missouri line. This locality is near Bronson and not a great distance from Erie, both of which names have been given to the beds near Uniontown. The section, slightly modified is:

SECTION WEST OF UNIONTOWN, KANSAS.

Number.	Stratum.	Thickness. Ft.	Thickness. in.
1	Limestone, white, upper 5 feet very cherty, lower 20 feet somewhat evenly bedded, with an occasional chert concretion (Winterset)	25	
2	Shale, bituminous	3	
3	Limestone, evenly bedded; two layers	1	6
4	Shale; somewhat argillaceous	9	
5	Limestone, upper part light-colored, sub-oolitic; lower part brecciated or heavy-bedded; even-bedded (Bethany Falls)	16	
6	Shale, clay and bituminous	4	
7	Limestone, evenly-bedded; two layers	3	
8	Shale, clay	7	
9	Limestone, unevenly and heavily bedded; weathering rough (Hertha)	22	
10	Shale, drab, argillaceous	3	
11	Limestone, dark; in two layers	1	4
		94	10

[1]Bennett, John, A geologic section along the Missouri Pacific Railway from State line, Bourbon County, to Yates Center: Kansas Univ. Geol. Survey, vol. 1, pp. 95-96, 1896.

No 9 of this section is correlated by the Kansas Survey with the Bethany Falls limestone (Broadhead's number 78); No. 5 with the "Mound Valley" limestone (Broadhead's numbers 83-84)= true Bethany Falls limestone; and No. 1 with the "Dennis' limestone (Broadhead's number 85a)= Winterset limestone. The writer, however, differs from this opinion in correlating No. 9 with the Hertha (Broadhead's number 74), No. 8 with 75-76a-b, No. 7 with 76, No. 6 with 77a-b, No. 5 with the Bethany Falls[1] 78-80, Nos. 3-4 with 81a, No. 2 with 81b-c, and No. 1 with the Winterset 82-85a. It will be seen that with the exception of the thickness of the lowest limestone, No. 9 or 74, there is a close agreement with Broadhead's section, even in the minor details. The "Mound Valley" and "Dennis" limestones at Kansas City as correlated by the Kansas Survey have no black shale between them; in fact, very little shale of any kind. In the writer's experience the thin beds of black shale are among the most persistent beds in the Missouri group and that this particular layer of black shale (No. 2 of above) should entirely disappear between Uniontown and Kansas City does not seem probable. As to the thickness of the lower limestone, it is known to thin to the north along the eastern outcrop, though in many deep drillings it exhibits a thickness of nearly 20 feet. No. 9 of the Uniontown section has been traced to the Missouri line, where it has been identified by Broadhead[2] as his number 74, the Hertha limestone.

The most southerly occurrence of the Missouri group in Missouri is on "Rock Mound" (sec. 5, T. 38 N., R. 33 W.), capped by the Hertha limestone. This member is here about eight feet thick, massive, ferruginous, dark gray on the weathered surface, lighter where freshly broken, and with a rough appearance. Its altitude is approximately 950 feet, about the same as the escarpment five or six miles to the west.

The Hertha limestone next appears in the county on a mound on the divide in T. 39 N., R. 33 W. From the north side of Marais des Cygnes River, the Hertha and Bethany Falls limestones cap a series of mounds along the State line to the vicinity of Mervin where the main escarpment enters the State, cuts across the northwest corner of Bates and enters Cass County. The Winterset limestone probably occurs in this area. Out-

[1]The Kansas Survey now concurs in this correlation in a letter to David White, dated May 14, 1912.

[2]Broadhead, G. C., The coal measures of Missouri: Missouri Geol Survey, vol. 8, p. 371, 1895.

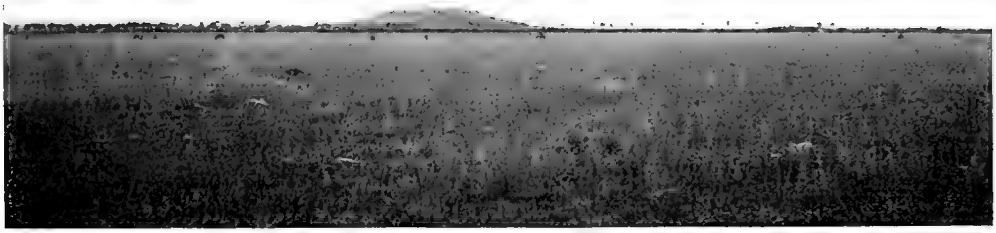

Fig. A. "Rock Mound" near Hume, capped by Hertha limestone.

Fig. B. Escarpment of Kansas City formation at Amsterdam.

liers of the Kansas City formation are found in Bates County as far east as the western part of T. 41 N., R. 30 W., at an altitude of about 1,000 feet. Some of these are capped with the Bethany Falls limestone, according to Broadhead.[1]

At the mound on the east line of sec. 13, T. 41 N., R. 32 W., the Hertha limestone is eight feet or more in thickness. It is a gray limestone with red ferruginous streaks and has a somewhat brecciated appearance. A fresh surface shows many sections of a shall of the Bellerophon type.

SECTION AT MOUND IN SEC. 1, T. 41 N., R. 32 W.

Number.	Stratum.	Thickness.
		Feet.
1	Soil, with chert	10
2	Limestone, gray, "brecciated" (Bethany Falls, base)	5
3	Shale, black, bituminous, and covered	3
4	Limestone, dark gray	1
5	Shale and covered	10
6	Limestone, massive (Hertha), about	4

Cass County.—The escarpment of Kansas City formation enters this county from the south on the western side of range 32 west, and crosses the county in an irregular line to the northeastern corner. The following section slightly modified from Broadhead, was taken at Pleasant Hill.

SECTION AT PLEASANT HILL, MO.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Shale, clay	4	
2	Limestone; decomposing bed; brownish; ochery= upper part of number 85		4
3	Shale, dark-drab, clay	4	
4	Limestone, buff; decomposing; with disseminated particles of calcite and fragments of crinoid stems	2	
5	Limestone, silicious, blue; weathers drab; fracture conchoidal	3	
6	Limestone, silicious, drab, fine-grained; with numerous specks of calc-spar disseminated; when not too cherty, admits of a fine polish	2	

[1]Broadhead, G. C. (Geology of) Bates County: Missouri Geol. Survey, Report for 1873-74, p. 161, 1874.

SECTION AT PLEASANT HILL, MO.—Continued.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
7	Limestone, rough and irregularly-bedded; grayish-drab; has buff, shaly partings; contains brown and white calcite; and rose-colored heavy spar; contains a peculiar cylindrical fucoid about an inch in diameter, the periphery of silicious cherty material studded within with minute quartz crystals; some with a calcite band between the inner and the outer part	8	
8	Shale, brown and buff, calcareous	1	6
9	Limestone, blue, shaly; turns brown on exposure	4	
10	Shale, bituminous	1	
11	Shale, blue and bituminous; with Cordaites and an occasional knife-edge of coal	3	
12	Clay, blue and buff	3	
13	Limestone, light-drab, fine-grained	2	
14	Limestone, oolitic and sub-crystalline; the oolitic bed is ferruginous	4	
15	Limestone, gray, shelly (=78)	10	
16	Shale, blue and bituminous	6	
17	Limestone and shale; fossiliferous	1	
18	Shale	4	
19	Limestone, gray; quite ferruginous in places	4	
		67	10

Number 19 is the Hertha; 16-18, the Ladore; 13-15, the Bethany Falls; 10-12, the Galesburg; 2-9, the Winterset. This section may be taken as a type of the base of the Kansas City formation throughout Cass County. In the western part of the county, the upper members of the formation also occur. The Iola limestone enters the State from Kansas in the northwest corner of the county.

Johnson County.—The Hertha and Bethany Falls limestones cap a series of narrow ridges and mounds in the extreme western part of the county, and in the extreme northwest corner the Winterset limestone probably occurs. The residual chert of the latter member is found in the southern part of T. 47 N., R. 29 W. The easternmost outcrop of the Hertha is on a mound in the east-central part of T. 47 N., R. 28 W., where its altitude is about 1,000 feet.

Jackson County.[1]—The formation, of which Kansas City, is the type locality, covers the greater part of the county. The Iola limestone, the upper member, extends east to Independence,

[1]A report on Jackson County is being prepared and will be published by this Bureau within a short time.

where it is the highest bed exposed. The following is a generalized section made in the vicinity of Kansas City and now on file in the office of the State Geologist at Rolla:

GENERALIZED SECTION OF THE KANSAS CITY FORMATION AT KANSAS CITY.

Stratum.	Broadhead's number.	Thickness.
		Feet.
Iola limestone member:		
Limestone, gray to buff; thinly-bedded; increasing in thickness from top to bottom; non-cherty; "Crusher ledge".	98	25–30
Chanute shale member:		
Shale, blue to olive; ocher concretions; fine-grained; slightly arenaceous	97	21–25
Limestone (Raytown bed), variegated, gray; large fossils; "Calico ledge"	96	5–8
Clay	—	(parting)
Limestone, blue	—	1–1½
Shale, bituminous and blue	95	2
Limestone	94	1–1½
Shale, blue	93	1–1½
Limestone, blue, shaly	92	1–1½
Shale, blue, buff and red	91	8–13
Limestone (Cement City bed), drab; fine-grained; "Building ledge," lower half-foot "fish tooth ledge"	90	9–10
Shale, blue and olive	89	4
Shale, yellow, nodular, ochery	88	3–4
Drum limestone member:		
Limestone, irregularly bedded	87b	2–3
Limestone, oolitic, gray; very fossiliferous; "Oolitic ledge"	87a	11–13
Shale, blue	—	1
Limestone, gray, seams buff, solid, fossiliferous, "Bull ledge"	—	6–7
Cherryvale shale member:		
Shale, dark	86	13–15
Limestone, shelly	—	1
Shale, drab	—	1
Limestone	—	1
Shale	—	2
Limestone	85d	1
Shale, buff	—	1
Shale, blue	85c	3
Coal	85b	—
Winterset limestone member:		
Limestone, dark blue; black chert in upper 4 ft. "Chert ledge"	85a	12–16
Shale, blue, slaty	—	4–5
Limestone, drab; fine-grained	84	3–8
Shale	—	½
Limestone	—	2
Shale	—	1
Limestone, blue to drab	83	3–5

GENERALIZED SECTION OF THE KANSAS CITY FORMATION AT KANSAS CITY—Continued.

Stratum.	Broadhead's number.	Thickness.
		Feet.
Winterset limestone member—Continued.		
Shale, blue	—	½
Limestone	82	1
Galesburg shale member:		
Shale, yellow, ochery	—	1
Shale, blue	81c	2
Shale, bituminous	81b	1
Shale, argillaceous	81a	2
Bethany Falls limestone member:		
Limestone, nodular, shelly	80	2–4
Limestone, oolitic	79	1
Limestone, grayish; upper 6 ft. mottled, lower crystalline; fine-grained	78	18–21
Ladore shale member:		
Shale, blue	77b	2–3
Shale, bituminous	77a	1–2
Limestone, dull	76c	1
Shale	76b	½
Limestone	76a	½
Shale, blue	75	2–3
Hertha limestone member:		
Limestone	74	6

The sections of Broadhead and Bennett essentially agree with that given. It will be seen that there is a shale parting in the Winterset limestone at this place. The lack of outcrops of the Hertha in the northern part of the city caused the parting in the Winterset to be mistaken for the Galesburg shale and resulted in the mix-up in correlation mentioned under the nomenclature of the Kansas City formation in Chapter I.

With the exception of the Drum limestone and the upper shale in the Chanute member, the formation is fairly regular throughout the county. The Drum is thin or absent in the southern part and is arenaceous in others.

Lafayette County.—The Kansas City formation is confined to a few narrow ridges and mounds in the western part of the county. As in nearly all mound outcrops, details can not be determined very satisfactorily. A section of the formation capping the hill at Greenton is as follows:[1]

[1]Marbut, C. F., Geological description of the Lexington sheet: Missouri Geol. Survey, vol 12, pt. 2, p. 215, 1898.

Cement City and Raytown limestones in Chanute shale at Kansas City.

SECTION OF KANSAS CITY FORMATION CAPPING HILL AT GREENTON.

Number.	Stratum.	Thickness.
		Feet.
1	Concealed. (soil)	12
2	Limestone	10
3	Shale	10
4	Limestone	3
5	Shale	6
6	Limestone	2

No. 2 is probably the Bethany Falls; No. 4, the Hertha; and No. 6, a lens in the upper part of the Pleasanton shale.

Platte County.—The Kansas City formation underlies all of this county, but is largely covered by higher formations. One exception is the Missouri River floodplain in the southern part of the county where erosion has cut through the base of the formation into the underlying Pleasanton formation. The outcrop of the Kansas City formation is mainly confined to the Missouri River bluffs but extends farther north in the southeastern corner. The upper members are shown especially well on Line Creek near the east county line.

The northernmost outcrop of the Winterset limestone on Missouri River is along the bluff road in the NE. ¼ sec. 6, T. 50 N., R. 33 W. The shale immediately above is a *Marginifera splendens* and *Chonetes verneuilianus* zone as at Kansas City and Quindaro.

Above the Winterset, a limestone in the Cherryvale shale (Broadhead's number 85d) is exposed for some distance. It is 14 inches thick, in two layers, and is a very hard, fine-grained blue stone that weathers to buff. It is little affected by freezing and thawing and has been quarried wherever practicable.

The Drum limestone on the north side of the river differs from its development at Kansas City in that it has largely lost its oölitic character and is a thin and irregularly bedded, cherty limestone. In the old quarry in the NE. ¼ sec. 5, T. 50 N., R. 33 W. only the upper three feet are oölitic. At the falls ½ mile below Parkville is the following:

SECTION ONE-HALF MILE BELOW PARKVILLE.

Number.	Stratum.	Thickness.	
		Ft.	in.
1	Limestone, shaly argillaceous (Cement City bed)	2	2
2	Limestone, argillaceous	8	
3	Shale, blue and bituminous	2	6
4	Limestone, thin-bedded, cherty (Drum)	14	
5	Shale, blue, argillaceous	—	—

The upper part of the Kansas City formation is better exposed in the bluff west of Parkville.

SECTION OF BLUFF WEST OF PARKVILLE.

Number.	Stratum.	Thickness.	
		Ft.	in.
1	Shale, greenish, arenaceous (base of Lane member of Lansing formation)	16	
2	Limestone, top foot brownish, crystalline, even-bedded; remainder thin-and wavy-bedded, irregular (Iola)	20	
3	Shale, blue and buff	27	
4	Limestone (Raytown bed)	4	2
5	Shale, greenish, calcareous		6
6	Limestone		7
7	Shale, brown, slaty, carbonaceous (No. 95)		10
8	Limestone (No. 92)	1	2
9	Slope; shale shows in places (No. 91)	9	

The Cement City bed and the Drum limestone outcrop for nearly a mile above Parkville and have been extensively quarried. The shale above the Cement City bed contains a conspicuous red layer near Parkville. The northernmost exposure of the Iola limestone in Platte County is about one mile southeast of Waldron, where 13 feet of it may be seen. In the various drillings at Leavenworth the members of the formation appear with few changes.

Clay County.—The Kansas City is the highest indurated formation over a large part of Clay County. The base of the formation is exposed along Missouri and Fishing rivers and the top outcrops in a sinuous line from the southwest to the northeast corner with an extensive inlier on Smith's Fork in the northwestern corner. Along the south side of the county, on the Missouri bluffs and also in the vicinity of Liberty, the lower members of the formation are extensively quarried.

Broadhead took the following section near Liberty Landing (South Liberty):

SECTION NEAR LIBERTY LANDING.

Number.	Stratum.	Thickness Ft.	in.
1	Limestone (No. 84)	10	
2	Shale, blue, argillaceous	1	
3	Limestone, bluish-gray; in irregular beds (Nos. 82-83)	6	4
4	Shale, bituminous (No. 81)	2	6
5	Shale, blue (No. 81)	2	
6	Limestone, dove-colored, nodular (No. 80)	4	
7	Limestone, whitish, oolitic (No. 79)	1	1
8	Limestone, dove-colored, thick-bedded; fucoidal (No. 78)	14	8
9	Limestone, gray; irregularly-bedded (No. 78)	6	
10	Shale, blue, argillaceous (No. 77)	2	2
11	Shale, bituminous (No. 77)	1	4
12	Limestone, argillaceous (No. 76)	1	6
13	Shale, blue, argillaceous (No. 76)		7
14	Limestone, concretionary (No. 75)		6
15	Shale, blue, argillaceous (No. 75)	2	6
16	Limestone, gray; weathers brown (No. 74)	4	
17	Limestone, gray; coarse-grained (No. 74)	2	6
		62	8

Numbers 16 and 17 are the Hertha limestone; 10-15, the Ladore shale; 6-9, the Bethany Falls; 4-5, the Galesburg; 1-3, the Winterset. This section may be considered typical for the lower part of the formation.

The entire thickness of the Winterset is shown in the section (Broadhead, modified) at North Missouri Junction (Birmingham):

SECTION AT BIRMINGHAM.

Number.	Stratum.	Thickness. Ft.	in.
1	Limestone, blue, containing crinoids	1	2
2	Shale, blue, argillaceous	2	6
3	Coal, black streak (base of Cherryvale)		4
4	Limestone, deep-blue, cherty, in irregular layers; at three feet from top are 10 inches of shale. "The top layer is shaly and abounds in remains of leaves of plants, probably Cordaites, on which are often found reposing univalves belonging most probably to the genera Pleurotomaria, Murchisonia and Loxonema. This shaly, black band passes into the next subordinate cherty beds. The fossils are generally of white chert composition on the outer crust and blue within, the chert layers deep-blue within, changing to decomposing white on the exterior surface"	8	8
5	Limestone in two thick beds; lower ash-blue	9	4

SECTION AT BIRMINGHAM—Continued.

Number.	Stratum.	Thickness. Ft.	in.
6	Shale, blue		5
7	Limestone, gray, in irregular layers	5	8
8	Shale, blue		5
9	Limestone, light-gray and somewhat concretionary (base of Winterset)	1	2
10	Shale, blue		11
11	Shale, bituminous	1	7
12	Shale, blue, argillaceous	2	
13	Limestone (Bethany Falls)	20	8
14	Shale, blue	2	
15	Slope to railroad track	5	

In the vicinity of Liberty the Winterset limestone is apparently somewhat irregular, as shown by the following section taken one and one-half miles east, where the road crosses Rush Creek:

SECTION ONE AND ONE-HALF MILES EAST OF LIBERTY.

Number.	Stratum.	Thickness. Ft.	in.
1	Limestone, very cherty at top (north of road)	14	
2	Shale, blue	8	
3	Concealed, no exact measurements could be made on account of dip, may be about	10	
4	Shale, calcareous, with limestone lenses (south of road)	3	
5	Limestone, argillaceous with black carbonized plant remains	1	
6	Shale		8–10
7	Limestone, argillaceous		8
8	Shale	1 ½–4	
9	Limestone, upper surface uneven with three feet relief in places; near the middle is a 5-inch shale parting; the stone above is argillaceous, and below, thin-bedded and purer	15	
10	Shale, blue		4–5
11	Limestone, argillaceous, grades into No. 12	1	6
12	Shale, blue, argillaceous (Galesburg)	1	2
13	Shale, black, slaty (Galesburg)	1	6
14	Shale, blue (Galesburg)	2	
15	Limestone (Bethany Falls)	2	

The relief at the top of No. 9 is suggestive of a local unconformity and for that reason the writer is uncertain as to whether the whole section above the Galesburg should be referred to the Winterset or whether it includes the Winterset, Cherryvale, and Drum members.

Northeast of Liberty, near the railroad tracks, are some quarries in a limestone which is possibly to be referred to No. 1 of this section. No good exposures occur below the limestone in these quarries. At the quarry west of the Burlington tracks, 1½ miles north, the following is exposed:

SECTION ONE AND ONE-HALF MILES NORTH OF LIBERTY.

Number	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone, gray	1	4
2	Shale, with thin streak of black shale near bottom	5	
3	Limestone, blue, very cherty at top (Drum?)	13	8
4	Covered	25	
5	Limestone, in bed of creek	—	

No. 1 of this section resembles Broadhead's number 85d, just above the Winterset, but a nearby exposure shows eight feet of blue shale below the heavy limestone, a thicker body of shale than known elsewhere in the Winterset limestone.

The beds above No. 3 of the foregoing section are exposed on Rush Creek about three miles northeast of Liberty, and measured as follows:

SECTION ON RUSH CREEK, THREE MILES NORTHEAST OF LIBERTY.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Shale, arenaceous, micaceous (Chanute)	15	
2	Limestone, gray (Raytown)		11–12
3	Shale, very calcareous (Raytown)	1	3
4	Shale (Raytown)		7
5	Limestone (Raytown)		6
6	Shale, black, slaty in middle (No. 95)		11
7	Limestone, gray (No. 92)		11
8	Shale, drab, argillaceous	4	
9	Covered	11	
10	Covered, oolitic, gray limestone at top, calcareous shale at bottom	5	
11	Limestone	1	1
12	Shale and covered	5	
13	Limestone, blue, cherty	6	
14	Limestone, thin-bedded, wavy; shaly partings	3	9
15	Shale parting		3
16	Limestone, like No. 14	1	
17	Shale parting		4–5
18	Limestone		1–2
19	Shale, blue; to water in Rush Creek	4	8

Numbers 13 to 18 are believed to be the Drum limestone.

Near Liberty the Raytown bed is fairly uniform. The black, slaty shale below is absent in places but small, round concretions mark its horizon. The upper shale bed of the Chanute varies from 11 to 32 feet; where thin, it is a blue argillaceous shale, but where the maximum thickness is attained, it is sandy and locally contains a thin coal seam. The upper member of the Kansas City, the Iola limestone, varies from 5 to 11 feet but its other characteristics are fairly constant.

In the vicinity of Smithville there is a rather extensive inlier of the Kansas City formation on Smith's Fork of Platte River. The section shows the same beds as at Liberty but with even a wider range in thickness. The following is a generalized section:

KANSAS CITY FORMATION NEAR SMITHVILLE, MO.

Number.	Stratum.	Thickness.
		Feet.
1	Limestone, gray, thin-bedded (Iola)	8–14
2	Shale, blue or gray (Iola)	½–1
3	Limestone, even layer; contains fossil sponges (Iola)	1
4	Shale, blue; argillaceous; calcareous at top in places (No. 97)	3–20
5	Limestone, thin-bedded, with shaly partings; a coarse-grained crinoidal layer at base (Raytown bed)	3–4½
6	Shale, black, slaty where thin, but with dark clay shale above slaty portion where thick (Nos. 93-95)	1–7
7	Limestone, even layer (No. 92)	½–1
8	Shale, blue or buff, contains a hard layer of micaceous sandstone in places	10–15
9	Limestone, gray (Cement City bed)	5–6
10	Shale, greenish (No. 91)	5–10
11	Limestone, gray, oolitic in places (Drum)	6–8
12	Shale, blue (Cherryvale)	9+

In the vicinity of Holt, Clay County, the upper part of the Kansas City formation is well exposed:

GENERALIZED SECTION NEAR HOLT.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone, thin-bedded, crystalline (Iola)	7	
2	Shale (Iola)	1	
3	Limestone like above (Iola)	1	8
4	Shale (No. 97)	15–20	
5	Limestone, gray; weathering buff; thick- to thin-bedded; with 2 feet of black, slaty bituminous shale 6-8 inches above bottom (Nos. 92-96)	6	

GENERALIZED SECTION NEAR HOLT—Continued.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
6	Sandstone; at top firm and micaceous; soft drab shale at bottom (No. 91)	15	
7	Limestone, gray to cream-colored; compact; sub-oolitic or shelly and argillaceous (Cement City)	3–5	
8	Shale, soft drab (Nos. 88-89)	15	
9	Limestone, gray; fine-grained with shale partings (Drum)	3	6
10	Limestone composed mainly of Fusulina		8
11	Shale, purple or blue; argillaceous (No. 86)	19	

Good outcrops of the Kansas City formation occur near Excelsior Springs. The following section, taken on Dry Branch, shows the greater part of the formation, though details are lacking.

SECTION AT EXCELSIOR SPRINGS.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone; upper foot buff, gray below; fine-grained; thick- to thin-bedded with chert (Iola)	6	
2	Covered, about	60	
3	Limestone, blue, weathering buff; cherty in upper part; with beds averaging 20 inches, thinner-bedded below (Winterset)	14	
4	Covered	15	
5	Limestone composed of unconsolidated nodules	2	
6	Limestone, massive, gray (with 5 is Bethany Falls)	14	
7	Shale, blue and bituminous (No. 77)	3	
8	Limestone (No. 76c)		3

No. 3 of this section certainly includes Broadhead's numbers 84 and 85a and possibly his 83b, and there are no partings of consequence, as at Liberty and Kansas City. The upper part of the Winterset weathers to a buff, brittle, shaly texture.

Ray County.—The Missouri group is represented in this county by the Kansas City and Lansing formations. The latter covers a very small area in the northwestern corner of the county, forming a part of the Lathrop upland. The three limestones at the base of the Kansas City formation cap a well-defined escarpment, extending in an irregular line from the southwest to the northeast corner of the county, and, in places, reaching an elevation of 150 feet above the lowland.

The easternmost outcrop of the Kansas City formation on the north bluffs of Missouri River is a little east of Orrick, where the Bethany Falls is about 15 feet thick and the Hertha about 5½ feet thick, with 9 feet of shale between them. In the vicinity of Rayville the thickness of the Bethany Falls limestone is 16 feet. It is known locally as the "Spotted rock." The Hertha limestone is 5 feet 2 inches to 5 feet 4 inches thick, in two layers with a shaly parting. The Ladore shale between these is about 10 feet thick here, but southeast of Lawson reaches nearly 20 feet. The Kansas City formation in the southeastern part of this county is discussed in detail in the report on the Richmond quadrangle.[1]

The higher beds of the formation are well exposed in the vicinity of Elmira:

SECTION ON CREEK NEAR RAILROAD, ONE MILE SOUTH OF ELMIRA.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone, gray; crystalline (Iola)	7	
2	Shale, arenaceous, micaceous; with streak of coal 15 feet above base (No. 97)	25	
3	Limestone and shale (Raytown bed)	5	
4	Covered slope	20	
5	Limestone, gray to almost white; suboolitic, massive to shaly (Cement City bed)	3–5	
6	Shale	15	
7	Limestone, nodular; in thin beds with heavier shale partings (Drum)	2	2
8	Shale	3	
9	Limestone, even-bedded, very fossiliferous		4–6
10	Shale, light blue; to bed of creek	3	

In the second cut south of Elmira, No. 5 of above is 10 feet thick, the lower two feet constituting a single layer, fine-grained at top and bottom and "conglomeratic" in middle, the remaining 8 feet being shaly, nodular limestone and inter-bedded shale.

In the first cut north of Elmira the section appears thus:

SECTION IN RAILROAD CUT NORTH OF ELMIRA.

Number.	Stratum.	Thickness.
		Feet.
1	Limestone (No. 92)	—
2	Shale, drab	5
3	Sandstone, firm, micaceous	3
4	Shale, drab	6
5	Limestone, like lower layer of No. 5 in last section (Cement City)	2
6	Shale, drab	15

[1]Marbut, C. F., Geological description of the Richmond sheet: Missouri Geol. Survey, vol. 12, pt. 2, pp. 252-308, 1898.

SECTION FROM CUT ON MILWAUKEE RAILROAD, ONE AND ONE-QUARTER MILES NORTH OF ELMIRA TO CREEK BELOW.

Number.	Stratum.		Thickness.	
			Ft.	*in.*
1	Limestone, dark, massive, fossiliferous (lower part of Iola)		1	9
2	Shale, sandy, micaceous; upper part dark and with ferruginous concretions, lower part lighter	(No. 97)	20	
3	Coal, impure	(No. 97)		4
4	Shale, like lower part of No. 2	(No. 97)	6	
5	Limestone, gray; composed of broken fossils	(Raytown)	1	
6	Shale	(Raytown)		4
7	Limestone, gray	(Raytown)		8
8	Shale, calcareous, and thin beds of limestone (No. 95)			6
9	Limestone, buff (No. 92)		1	6
10	Shale, sandy, and sandstone		19	
11	Limestone, impure; nodular; rough; weathering shows interbedded shale (Cement City)		10	
12	Covered, about		25	
13	Limestone, gray, massive; sub-oolitic (Drum)		1	2
14	Covered to bed of branch near Crooked River		3	

The limestone correlated with the Iola in this section is probably the lower part of that member, as it develops a rather persistent shale parting near the base in this region, as shown in the section near Holt, Clay County. The Chanute shale is much more arenaceous in the upper portion than it is farther south and contains a thin coal seam. Six inches is the maximum thickness of coal known and this is probably a local thickening. The black shale usually found below the Raytown bed is poorly developed here but at its horizon are small round concretions. The Drum limestone is poorly exposed at this place and is probably of greater thickness than given in the section.

Carroll County.—The Kansas City formation is represented in Carroll County by the three basal limestones and the interbedded shales in the northwestern corner of the county and in the Blue Mound region in the north central part. These areas are table lands, rather even on top, standing 100-200 feet above the surrounding country.

GENERALIZED SECTION IN THE BLUE MOUND REGION.

Number.	Stratum.		Thickness.
			Feet.
1	Limestone, gray; composed largely of Fusulina; not seen in place	(Winterset)	—
2	Limestone, gray, thin-bedded	(Winterset)	6– 8

GENERALIZED SECTION IN THE BLUE MOUND REGION—Continued.

Number.	Stratum.	Thickness.
		Feet.
3	Shale, blue; argillaceous, and black bituminous (Galesburg)	8
4	Limestone, gray (Bethany Falls)	10
5	Interval with sandy shale and firm sandstone in lower two-thirds (Ladore)	20–28
6	Limestone, gray; weathering brown (Hertha)	4½

It is safe to assume that the upper part of No. 5 contains black shale and a thin bed of limestone above the shale and sandstone. The latter is very resistant and quartzitic in places. The Ladore shale has here thickened here quite perceptibly.

The upper layer of the Bethany Falls weathers to a brown, porous material in many of the outcrops in this region. The lower layers show the thin-bedded oölitic phase of this limestone.

Buchanan and Clinton counties.—The Iola and Chanute members of the Kansas City formation outcrop near the southeastern and northeastern corners of Clinton County but are concealed in most of it and in all of Buchanan County by higher formations. The records of borings at Lathrop,[1] Cameron, Stewartsville, and Saxton, Mo., and Atchison, Kans., show the character of the formation in these counties to be similar to that of other counties lying south and east.

Caldwell County.—The greater part of the county is underlain by the Missouri group, which is represented by both the Kansas City and Lansing formations. The latter is found in the northwest corner and along the western edge of the county. In the vicinity of Braymer the escarpment formed by the three lower limestones of the Kansas City, is well developed as shown by the profile of the Chicago, Milwaukee and St. Paul Railway. Braymer, below the escarpment has an altitude of 755 feet, while Cowgill, west of the escarpment, is 960 feet above sea level. In the railroad cut two miles east of Cowgill, 12-14 feet of the Winterset limestone is exposed. It is here a thinly bedded, finely crystalline, gray limestone. The main ledge of the Bethany Falls is 11½ feet thick. Over most of its outcrop it has the

[1]For Lathrop record, see Hinds, Henry, The coal deposits of Missouri: Missouri Bureau of Geology and Mines, vol. 11, 2d series, pp. 156-157, 1912.

mottled texture that is present at the type locality and at Missouri City.

The following is a section showing the succession at the quarry of the Breckenridge Stone Company north of Breckenridge[1]:

SECTION IN QUARRY OF BRECKENRIDGE STONE COMPANY NORTH OF BRECKENRIDGE.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Red dirt stripping	2	
2	Limestone, gray, thin, irregularly bedded; contains specks of calcite and fossils; very little iron	6	
3	Shale, blue	1	
4	Shale, fissile, bituminous	1	6
5	Shale, bluish, argillaceous	2	6
6	Limestone, gray, heavily bedded; somewhat shelly on surface; upper portion of the ledge shows small specks of iron oxide which gives the stone a slightly brownish color; center of the ledge has an oolitic texture	17	
7	Shale, yellowish-buff		6
8	Limestone, gray		10
9	Shale, blue to dark; non-arenaceous; grades into the bed below	1	6
10	Shale, fissile, bituminous	1	6
11	Limestone, bluish-black; probably contains considerable iron		10
12	Shale, bluish; of a non-arenaceous nature	12	
		47	2

Numbers 9-12 are included in the Ladore shale; numbers 6-8 are the Bethany Falls limestone; 3-5 the Galesburg shale; and 2 is the lower part of the Winterset limestone. The parting at the base of the Bethany Falls is characteristic of this limestone in much of its outcrop in the north-central counties of the State.

The higher beds of the county are exposed in the northwestern part. At the quarry north of the Burlington Railroad east of the Caldwell-DeKalb county line, are:

[1]Buehler, H. A., Lime and cement resources of Missouri: Missouri Bureau Geology and Mines, vol. 6, 2d ser., p. 108, 1907.

SECTION NORTH OF BURLINGTON RAILROAD NEAR THE CALDWELL–DEKALB COUNTY LINE.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Shale, calcareous; a mass of fossils	2	
2	Limestone, gray, resistant	1	
3	Shale, clayey at bottom; black, bituminous at top	1	4
4	Shale, buff; brittle; calcareous; grades into No. 5	2	
5	Limestone, buff; shaly and sandy	4	
6	Shale and nodular impure limestone	1	9
7	Limestone; in bed of branch; irregular; very uneven on top	2	8

Nos. 1 and 2 agree faunally with Nos. 12 and 13 of the Winston, Daviess County section, and are to be correlated with the Iola limestone. They probably represent only the lower layer of this member as exposed in northern Clay and Ray counties.

One-fourth mile to the north and at a slightly higher level the following section was measured:

SECTION ONE-FOURTH MILE NORTH OF BURLINGTON RAILROAD NEAR CALDWELL—DEKALB COUNTY LINE.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone, buff	1	4
2	Limestone, thin, irregular beds; shaly	2	
3	Shale, with thin, irregular limestones	1	3
4	Limestone; thin, irregular, and with unevenly bedded shales	2	4
5	Shale, drab, argillaceous	5	6
6	Shale, black, slaty	1	5

The last section dips strongly to the south and underlies the preceding section. The Nos. 1-4 of the last section constitute the Raytown bed of the Chanute shale member, and the black shale below is Broadhead's number 95. Numbers 5-7 of the first section may also be the Raytown bed but if so Broadhead's number 97, 13 feet thick a few miles north, has thinned to $3\frac{1}{3}$ feet at this place. It is more likely that the limestones below the Iola in the first section are merely local lenses in the upper layer (number 97) of the Chanute shale.

The core drilling at Cameron shows the following at this horizon:

PART OF LOG OF CORE DRILLING AT CAMERON.

Number.	Stratum.	Thickness.
		Feet.
1	Shale, calcareous	4
2	Limestone	4
3	Limestone	11
4	Shale, gray	4
5	Shale	4
6	Shale, black, slaty	2

From this it appears that the Iola member and the Raytown bed of the Chanute member form but one limestone near Cameron.

Livingston County.—The Kansas City formation occurs on the south edge of this county as a northern extension of the Blue Mound of Carroll County, in the southwest corner as a continuation of the ridge between Mud Creek and the "Low Gap" area, on the divide between Shoal Creek and Grand River, in the northwestern portion on the divide between the two forks of Grand River, and in a small area northwest of Wheeling. With the exception of the latter locality, the basal limestones of the group form a well-marked escarpment, in places nearly 200 feet high. It is also possible that outliers of the Hertha limestone may occur on the higher ridges in the northeastern part of the county but the presence of the drift makes it impossible to determine this.

The Drum limestone is probably the highest member of the formation represented in the county and occurs only in the extreme northwest corner. (See Grundy County.)

BROADHEAD'S GENERALIZED SECTION OF LIVINGSTON COUNTY.

Number.	Stratum.		Thickness.	
			Ft.	in.
1	Limestone, nodular and fine-grained; marble bed (No. 84)		2	6
2	Limestone, bluish; irregular layers	(No. 83)	3	
3	Shale, buff, and limestone	(No. 83)	2	
4	Limestone; even layers (No. 82)			9
5	Shale (No. 81c)		1	9
6	Shale, bituminous (No. 81b)		2	
7	Limestone, nodular (No. 80)	Bethany Falls limestone, locally called "cotton rock"	3	
8	Limestone, oolitic (No. 79)	Bethany Falls limestone, locally called "cotton rock"	8	5
9	Limestone (No. 78)	Bethany Falls limestone, locally called "cotton rock"	10	
10	Shale, blue (No. 77b)		5	
11	Shale, bituminous (No. 77a)		1	6
12	Limestone (No. 76)			10
13	Shaly slope (No. 75)		10	
14	Limestone, ferruginous (No. 74)		7	

In a cut on the Chicago, Burlington and Quincy Railroad in the northeast corner of section 22, T. 57 N., R. 25 W., is:

SECTION ONE AND ONE-HALF MILES EAST OF MOORESVILLE.

Number.	Stratum.	Thickness. Ft.	in.
1	Limestone, shaly	3–4	
2	Limestone, gray, thin-bedded, sub-oolitic	6	
3	Shale	1	8
4	Limestone, gray		10
5	Shale, argillaceous	2	6
6	Shale, black, fissile, bituminous	1	3
7	Limestone, nodular		3–6
8	Shale to bottom of trench	1	

Numbers 1-4 are the Bethany Falls limestone, the remainder the Ladore shale. The parting near the base of the Bethany Falls is a constant feature in this part of the State.

West of Utica (W. ½ NE. ¼ sec. 14, T. 57 N., R. 25 W.), Broadhead took the following section:

SECTION ON SOUTH BLUFF OF GRAND RIVER, TWO MILES WEST OF UTICA.

Number.	Stratum.	Thickness. Ft.	in.
1	Limestone, irregularly bedded	3	
2	Shale, olive and drab	1	6
3	Shale, bituminous	1	
4	Shale, dark, clayey	1	
5	Limestone, nodular		6
6	Limestone, gray, oolitic	3	
7	Limestone, oolitic, even layer	1	5
8	Limestone, oolitic	1	4
9	Limestone, oolitic	2	6

Numbers 5-9 are included in the Bethany Falls; 3-4, the Galesburg shale; and 1, the lower part of the Winterset.

The Ladore shale varies from 25 to 30 feet in thickness. In the Blue Mound area and at Spring Hill, a resistant, almost quartzitic, ripple-marked sandstone is found in the lower half of this shale.

In secs. 22 and 23, T. 58 N., R. 23 W., the Hertha, Bethany Falls, and Winterset limestones and intervening shales are seen dipping beneath a branch. At this place the Hertha is divided by several partings. The Bethany Falls is the same as in the sections given above. The following is a section of the Winterset limestone and Galesburg shale:

SECTION NEAR HALLOWEEN STORE.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone; thin wavy beds, with buff shaly partings, cherty; divided into three beds by partings	15+	
2	Shale, light, argillaceous; grading into next below	2	
3	Shale, black, fissile, bituminous	2	
4	Limestone; wavy on lower surface		3–5
5	Shale, drab, argillaceous	5	

Linn County.—The Missouri group may be present in the high ridges in the northern part of this county. It outcrops in the southern part of Sullivan, not far north of the Linn County line.

The Hertha and Bethany Falls limestones may also be represented by two limestones near Woodland Mills in sec. 14, T. 57, N., R. 21 W. The limestone correlated with the Hertha is five feet thick, and nearby are fragments of a limestone resembling the Bethany Falls.

Holt and Andrew counties.—No outcrops of the Kansas City formation occur in either of these counties, the stratigraphy being known only from the deep drillings in Holt County at Forest City (see p. 215) and Oregon.

DeKalb County.—Outcrops of the Kansas City formation are confined to the lower course of Grindstone Creek near where it passes out of the county. The following section was measured near Weatherby in a ravine north of the Rock Island Railroad (center of the SE. ¼, NW. ¼, sec. 25, T. 59 N., R. 30 W.):

SECTION NEAR WEATHERBY.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone, gray and shale; very calcareous; nodular; fossiliferous (Raytown bed)	2	
2	Shale, argillaceous	9	
3	Shale, black, slaty, bituminous (No. 95)	1	
4	Limestone, nodular (No. 92)		4
5	Shale	12	
6	Limestone; nearly white; uneven at top (Cement City)	1	7
7	Limestone, nodular, and buff, and buff calcareous shale (Cement City)	2	6
8	Shale	2	2
9	Shale, argillaceous; tinged with red in places	6	6
10	Limestone, buff and cream-colored (Drum)	3	

The following section taken in Daviess County, in the center of sec. 19, T. 59 N., R. 29 W., on the south side of the creek, shows the character of the lowest beds found in the county:

SECTION ABOUT A MILE EAST OF WEATHERBY, IN DAVIESS COUNTY.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Shale, with thin regular layers of limestone	8	
2	Limestone, gray (Broadhead's 85d)	2	
3	Shale, blue, clayey (Broadhead's 85d)	1	2
4	Limestone, nodular (Broadhead's 85d)		4

The whole section is in the Cherryvale shale.

Daviess County.—With the exception of the flood-plain of Grand River, the entire surface of this county is underlain by the Missouri group, which is represented by both the Kansas City and Lansing formations. The lowest members occur along Grand River. Buehler[1] gives a section along the railroad track east of Gallatin, which in substance is as follows:

SECTION NEAR GALLATIN.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone, gray, fossiliferous; weathered shelly along the crest of ridge	6	
2	Limestone, gray, fossiliferous; rather thinly-bedded; showing occasional small nodules of black chert	3	6
3	Shale slope	2	
4	Limestone, gray; irregularly bedded; fossiliferous; showing numerous specks and irregular markings of calcite	8	
5	Shale, dark, bluish	1	3
6	Shale, black	1	6
7	Shale, slope	5	
8	Limestone, gray; nodules of disintegrated limestone	5	
9	Limestone, gray; weathered to buff along joints; upper portion somewhat mottled (Bethany Falls)	9	6
10	Shale		2
11	Limestone		5
12	Shale, bluish-gray		6
13	Limestone		8
14	Shale, lower portion black; carbonaceous; upper portion gray to buff	4	6
15	Limestone, gray, heavy bed, fossiliferous	1	2
16	Shale	3	

[1]Buehler, H. A., Lime and cement resources of Missouri: Missouri Bureau of Geology and Mines, vol. 6, 2nd series, pp. 125-126, 1907.

Numbers 14-16 are included in the Ladore shale; 8-13 in the Bethany Falls limestone; 5-7 in the Galesburg shale, and 1-4 in the Winterset limestone.

Broadhead gives a section at Gallatin; this section, slightly modified, is as follows:

SECTION AT GALLATIN (BROADHEAD'S SECTION 120).

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Slope to hill top	35	
2	Limestone, coarse, ferruginous	1	
3	Slope	2	
4	Limestone, drab, rough-looking	1	6
5	Shale	8	6
6	Limestone, drab and brown; ferruginous; upper part is very fine-grained; compact	2	6
7	Shale, with thin beds of fossiliferous limestone	2	6
8	Shaly slope	23	
9	Limestone, bluish-drab; irregular-bedded; with vein of calcite (No. 87)	4	
10	Slope	16	
11	Limestone, hard blue, coarse (No. 85d)	1	
12	Slope (No. 85c)	2	
13	Limestone, light-drab, nodular and shelly; fine-grained; full of small holes (No. 84c)	8	
14	Limestone, drab, sub-oolitic	1	6
15	Limestone, bluish-drab, irregular-bedded, with shale partings and chert concretions (No. 83)	5	6
16	Limestone, shaly, irregular and concretionary (No. 83)	2	
17	Limestone, in apparently thick beds, but separated by irregular lines of deposit (No. 83)	2	7
18	Shale, with two thin concretionary limestone beds (No. 83)	2	
19	Limestone, deep blue, shaly, fucoidal (No. 83)	2	6
20	Limestone, gray; in 4 beds like No. 15	2	2
21	Shale, olive		10
22	Shale, bituminous	1	
23	Shale, blue and black; passing to a blue fire clay beneath	4	
24	Slope, a few feet	—	—
25	Limestone (Bethany Falls) (No. 78)	10 +	

The numbers given are Broadhead's own designation of the beds. Nos. 13-20 compose the Winterset; 10-12 the Cherryvale shale; 8-9, the Drum limestone; and 1-8, the Chanute shale; No. 6 is Broadhead's No. 90, the Cement City bed. No. 8 would probably show purple shale if exposed. The section shows a close correspondence to that east of Jamesport in Grundy County. From Gallatin to the west county line, there are outcrops of the Kansas City formation along Grand River. The Bethany Falls dips below that stream southwest of Pattonsburg.

A section taken northwest of Pattonsburg (NW. ¼ sec. 14, T. 61 N., R. 29 W., from Big Creek to wagon road to west) is as follows:

SECTION NORTHWEST OF PATTONSBURG.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone; nodular, impure, coarse- and fine-grained......	1	6
2	Shale, very calcareous..............................	5	6
3	Shale, drab, mottled with purple; argillaceous; thinly laminated..................................	13	
4	Limestone; gray; fine-grained; wavy on top..............	2	
5	Limestone, buff, with Fusulina........................	2	
6	Shale, buff, calcareous..............................	4	
7	Limestone, gray, sub-oolitic; massive or in two or three layers..................................	3	
8	Shale, buff; calcareous; with thin nodular layers of limestone..................................	8	
9	Shale, yellow; somewhat sandy........................	3	
10	Shale, blue, clayey..................................	3	
11	Shale, with thin even beds of limestone; total thickness evenly divided between shale and limestone............	10	
12	Limestone, dark-gray; in several layers................	2	
13	Covered (shale)....................................	2	
14	Limestone, shelly..................................		2
15	Shale..		4
16	Limestone..		4
17	Limestone, blue, resistant...........................		8–10
18	Limestone, nodular; two layers with shaly parting........		10
19	Limestone, shaly, and shale..........................	4	
20	Limestone, with Fusulina............................	2	
21	Limestone, thin-bedded; cherty; with buff, wavy partings	18	
22	Covered to water in Big Creek........................	3.	

Numbers 20 and 21 are Broadhead's numbers 83-85a, the Winterset limestone, and 14-17 are his number 85d at the base of the Cherryvale. Number 12 is a lens like those quite common at this horizon in the northern part of the State. Numbers 8-9-10-11 are Broadhead's No. 86, the thin alternating beds of shale and limestone being the characteristic part of this shale and outcropping over the surrounding country wherever the horizon is exposed. Numbers 4-7 represent the Drum, and No. 1, Broadhead's number 90, the Cement City limestone bed.

The section is continued in a hollow north of the track about 4½ miles northwest of Pattonsburg:

SECTION FOUR AND ONE-HALF MILES NORTHWEST OF PATTONSBURG.

Number.	Stratum.	Thickness. Ft.	in.
1	Soil, with fragments of weathered chert	—	—
2	Shale	—	—
3	Limestone, gray; fossiliferous; impure		4
4	Shale, blue; argillaceous	30	
5	Limestone, blue; shelly; fucoidal; thin-bedded	2	
6	Limestone; even layer, like above		7
7	Shale, dark; argillaceous; grading into next below	3	
8	Shale, black; fissile; bituminous	3	
9	Shale, dark drab; argillaceous		6
10	Limestone, very nodular		8–12
11	Shale, blue	1	

Number 10 is correlated with Broadhead's number 92; No. 9 with numbers 93 and 94; 8 with number 95; 5-6 with number 96; and 3 with number 100, the Farley limestone bed. It will be noted that the Iola has entirely disappeared here. The section closely resembles those at Gentryville and Bethany, Mo.

Owing to the numerous fine exposures on Grindstone Creek drainage, in the vicinity of Winston, a very complete section was obtained there. The Kansas City formation is rather low topographically. The generalized section is as follows:

GENERALIZED SECTION IN THE VICINITY OF WINSTON.

Number.	Stratum.		Thickness. Ft.	in.
1	Shale, calcareous, nodular; full of fossils	(No. 98)	1	6
2	Limestone, gray, massive	(No. 98)	1	
3	Shale; calcareous at top; blue and argillaceous at bottom		12	
4	Limestone; with shaly partings	(No. 96)	2	
5	Shale, with calcareous nodules	(No. 96)	3	
6	Limestone; thin nodular layers with interbedded shale	(No. 96)	2	
7	Shale, argillaceous	(No. 95)	5	
8	Shale, black, slaty, bituminous	(No. 95)	1	6
9	Shale; with micaceous sandstone near middle		13	
10	Limestone; light gray above; nodular and buff below (No. 90)		4	
11	Shale; lower 6 inches calcareous		13	6
12	Limestone			5–6
13	Shale, blue with red blotches		2	

Numbers 3-13 are correlated with the Chanute shale, 4-6 with the Cement City limestone bed, and 1-2 with the Iola limestone.

Grundy County.—The Kansas City formation outcrops in the western and northern portions of this county. The highest bed is probably the Cement City limestone bed near the middle of the Chanute shale member; it outcrops in the extreme southwest corner of the county. The sections below give the complete succession found in the county. The first was taken at the quarry, due west of Trenton, on the high bluff west of Grand River:

SECTION AT QUARRY WEST OF TRENTON.

Number.	Stratum.	Thickness. Ft.	Thickness. in.
1	Limestone, very shaly, nodular	3–4	
2	Limestone, light gray; suboolitic; cross-bedded; with occasional chert concretions	18	
3	Shale, blue, clayey	2	
4	Shale, black, slaty, bituminous	1	
5	Limestone, dark; in two layers	1	
6	Covered	15	
7	Limestone; two or three thin layers with interbedded shale	1	
8	Limestone, gray, weathers reddish-brown; in two layers	4	6
9	Shale, clayey	2-3	
10	Coal		2

Numbers 1-2 are the Bethany Falls limestone; 3-7 the Ladore, shale; and 8, the Hertha limestone.

East of Jamesport, in the southwest corner of the county, a cut on the Rock Island Railroad near Gee Creek, between Hickory Creek station and Jamesport, shows:

SECTION ON ROCK ISLAND RAILROAD, WEST OF HICKORY CREEK STATION.

Number.	Stratum.	Thickness. Ft.	Thickness. in.
1	Limestone, gray, massive; composed of fossil fragments (No. 87)	1	6
2	Limestone, yellowish; in 3 or 4 layers; very nodular and impure (No. 87)	2	3
3	Shale, yellowish; calcareous; with thin lens of limestone		9
4	Shale, blue, clayey; with thin even layers of limestone; at top yellow and slightly arenaceous	19	6
5	Limestone; six thin layers with shale partings	4	
6	Shale, blue	2	2
7	Limestone, very fossiliferous		3–6

SECTION ON ROCK ISLAND RAILROAD, WEST OF HICKORY CREEK STATION—Continued.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
8	Shale		6
9	Limestone		6
10	Shale		1–2
11	Limestone, blue, wavy-bedded (No. 85d)	1	
12	Limestone; nodular in 1 or 2 layers (No. 85d)		8
13	Shale		4
14	Limestone		7
15	Shale, blue; contains finely preserved fossils	6	
16	Limestone, thin-bedded, lenticular	¼–1	
17	Shale; upper 2 feet argillaceous; grades into loose calcareous nodules at bottom	8	
18	Limestone, fine-grained; in 4 layers	3	8
19	Limestone, shaly or shale,	1	3
20	Limestone; composed largely of Fusulina	1	
21	Limestone, argillaceous	2	9
22	Shale, blue; with two nodular layers of limestone	2	
23	Limestone, thin-bedded, cherty; buff shaly partings	3	
24	Shale parting		8
25	Limestone, like No. 23	4	6
26	Shale parting		6–8
27	Limestone, like No. 25	4	10
28	Shale, dark		6
29	Shale, black, slaty, bituminous	2	6
30	Shale, blue, clayey	6	
31	Limestone; upper shaly nodular portion of Bethany Falls, to track (No. 80)	1	6

The whole of the Bethany Falls is exposed a short distance southwest. Nos. 18-27 are included in the Winterset, Nos. 11 and 12 are Broadhead's number 85d, and 1-2 the Drum limestone.

The following section was measured one hundred yards west of road in center of sec. 30, T. 60 N., R. 25 W.:

SECTION IN THE SOUTHWESTERN PART OF GRUNDY COUNTY.

Number.	Stratum.	Thickness.
		Feet.
1	Limestone, "brecciated", fragmental (Cement City)	3
2	Covered	23
3	Limestone, gray, massive; composed of broken fossils	1

No. 3 is No. 1 of the last section; No. 2 probably contains red shale near the middle.

Atchison, Nodaway and Worth counties.—The stratigraphy of the Kansas City formation in these counties is known only from drill records. The core drilling at Maryville shows it in great detail.

Gentry County.—Outcrops of the Kansas City formation are confined to the southeastern corner of the county along the "breaks" of Grand River, the rest of the county being covered by the Lansing and Douglas formations. The following section (after Broadhead) taken in sec. 28, T. 61 N., R. 30 W., shows probably the lowest beds in the county:

SECTION NEAR GENTRYVILLE.

Number.	Stratum.		Thickness.	
			Ft.	*in.*
1	Limestone, fine fossils (Iola)		2	
2	Shale (top of Chanute)		5	
3	Limestone, blue, shelly	(Raytown)	1	6
4	Shale	(Raytown)		6
5	Limestone, nodular	(Raytown)	1	5
6	Clay		2	6
7	Shale, slaty (No. 95)		1	9
8	Limestone (No. 92)			5
9	Shale, blue (No. 91)		3	6
10	Slope		2	6
11	Limestone; full of fossils (Cement City)		3	
12	Shale		10	
13	Limestone, buff		2	
14	Shale (base of Chanute)		4	
15	Limestone, light drab	(Drum)	1	6
16	Clay, light-colored, and limestone nodules	(Drum)	5	
17	Limestone	(Drum)	3	
18	Shale (top of Cherryvale)		1	
19	Limestone, blue			5
20	Shale		3	
21	Limestone		1	

The upper part of this section is also exposed near Gentryville and shows no changes.

Harrison County.—The entire area of this county, with the exception of a strip bordering Grand River on the eastern side, is underlain by rocks of the Kansas City formation with a covering of glacial till and possibly also of the Lansing formation in places. Over most of the county the number of exposures is rather limited because of the heavy mantle of drift.

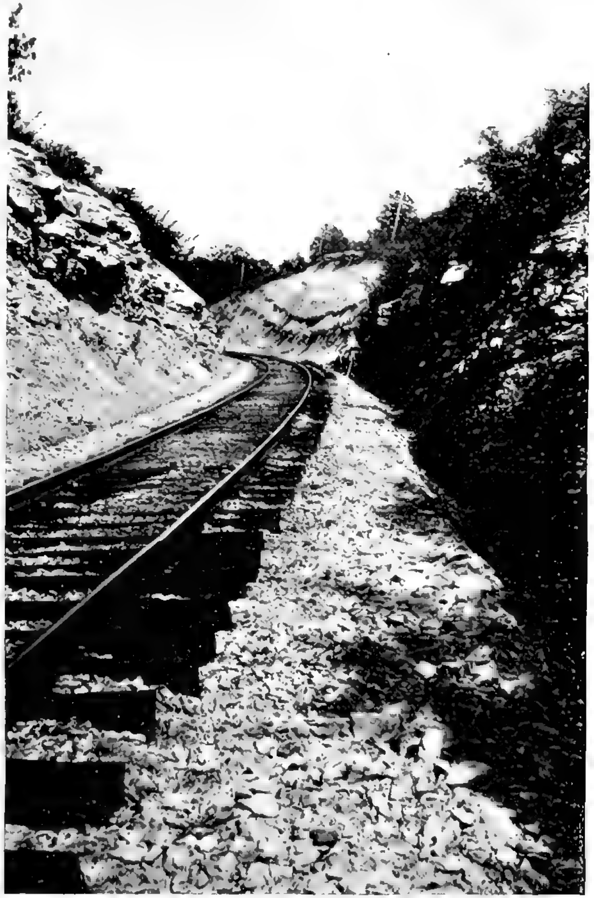

Fig. A. Winterset, Cherryvale and Drum members in railroad cut east of Jamesport.

Fig. B. Nearer view of Cherryvale shale and Drum limestone at same place.

SECTION ALONG TOMBSTONE CREEK, WEST OF MELBOURNE.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Slope with fragments of "brecciated" limestone	—	—
2	Limestone, buff, oolitic; uneven layers with interbedded shale (Drum)	5	6
3	Shale, buff; with nodular limestone (No. 86)	5	6
4	Shale, blue; with very even alternating beds of blue limestone	12	
5	Unexposed	—	—
6	Limestone, dark-blue; wavy on top and bottom	1	
7	Limestone, like above		3
8	Shale, clayey		5
9	Limestone (only top exposed)	—	—
10	Unexposed (base of Cherryvale)	—	—
11	Limestone, gray; with Fusulina, about	5	
12	Limestone, blue, cherty; thin wavy beds with buff shale partings (base of Winterset)	18	
13	Shale; with black, slaty, bituminous shale in middle (Galesburg)	8	
14	Limestone, nodular, shaly	4	
15	Limestone; thick-bedded at top, resembling the Bethany Falls at type locality, lower part thin-bedded as at Cainesville and Princeton (base of Bethany Falls)	14	
16	Shale, drab, clayey	2	3
17	Shale, black, slaty, bituminous	1	6
18	Limestone		4
19	Shale, sandy (base of Ladore)	12	
20	Limestone, gray (Hertha)	{ 2	2
		{ 1	6

The Falls of Big Creek at Bethany is the type locality of the Bethany Falls limestone. It has been described so fully that it would be useless to repeat the descriptions here. There are, however, two very different phases of this bed, which, not being recognized as such, have caused some misconceptions as to the correlation.

Bain[1] gives the following section in the western part of Bethany:

BAIN'S SECTION AT BETHANY.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Shale, clayey drab		6
2	Shale, calcareous; transition beds	1	6
3	Limestone, heavy ledge; many *Fusulina cylindrica*	2	10
4	Limestone, thinly bedded	10	
5	Unexposed	8	
6	Limestone, thin-bedded	12–15	

[1]Bain, H. F., Geology of Decatur County: Iowa Geol. Survey, vol. 8, pp. 255-314, 1897.

"The rock forming the falls lies probably 6 or 8 feet below the base of the limestone just described. It is about twenty feet thick."

As now exposed, the upper part of the section above No. 5 is as follows:

SECTION AT SPERRY QUARRY, BETHANY.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Shale, brown, and thin beds of limestone	4	
2	Shale, gray, and thin limestones	2	
3	Limestone, gray, massive; with Fusulina and black chert concretions	4	2
4	Limestone like above	2	4
5	Shale, buff, calcareous, and thin limestones	2	4
6	Limestone, thin-bedded; with buff, shaly, wavy partings.	4	

These beds are now better exposed at the quarry near the junction of the two forks of Big Creek, as shown in the following section:

SECTION SOUTH OF BETHANY ON BIG CREEK.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone, nodular, and shale	1	
2	Limestone, blue; wavy on upper and lower surfaces	1–1 ¼	
3	Limestone, blue; lenticular and concretionary		3
4	Shale, bluish	1	
5	Limestone, nodular; with shale partings	1	
6	Shale, drab, argillaceous, fossiliferous	3	6
7	Shale, buff, calcareous	3	
8	Shale, blue to buff, gritty	3	
9	Limestone, bluish, nodular	2	6
10	Shale, dark; nearly black; a mere film to	1	
11	Limestone, gray, heavy-bedded; contains a few cherty concretions	6	9
12	Limestone, dark-bluish; thin-bedded; cherty; shale partings which weather buff; fossiliferous	7	10
13	Concealed; with limestone at top in floor of quarry	16	
14	Limestone, gray; to bed of creek (Bethany Falls)	8	

Number 13 contains the Galesburg shale and the lower part of the Winterset, as may be seen by comparison with the Melbourne section. The top of the Winterset is placed at No. 11 but may include No. 9. The remainder belongs to the Cherryvale, the lower part of which is the equivalent of the upper part of the two previous sections.

Fig. A. Bethany Falls limestone at type locality near Bethany.

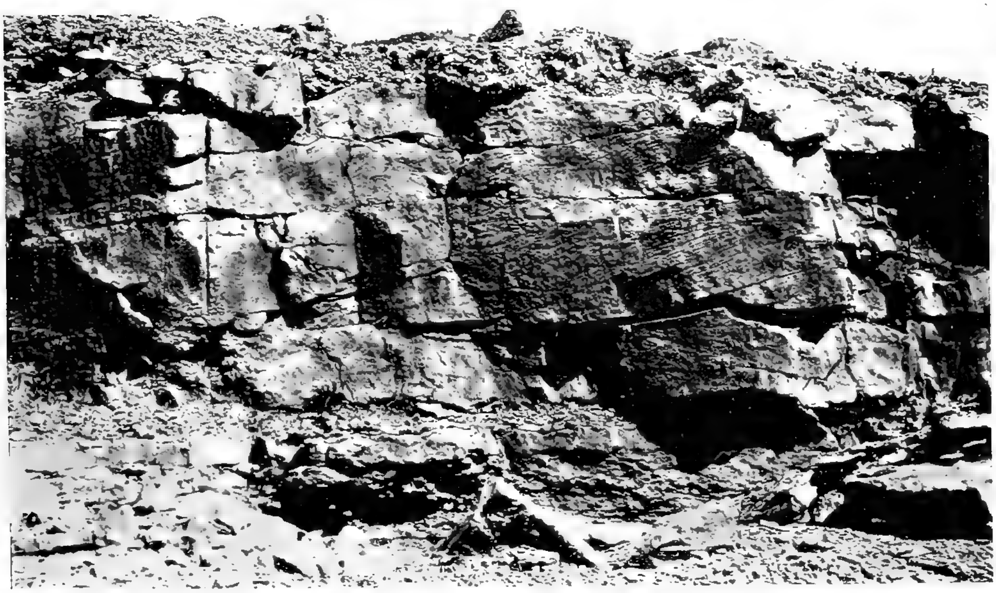

Fig. B. Bethany Falls limestone in quarry three miles south of Princeton.

Another phase of these beds is shown in the following section:

SECTION NEAR NORTHWEST CORNER SEC. 27, T. 63 N., R. 28 W.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone, dark blue, silicious; with white specks; wavy-bedded, in 2 or 3 layers	2	6
2	Shale; calcareous to clayey; dark when fresh; light gray when weathered; 3-inch nodular limestone near bottom	2	6
3	Limestone, very fossiliferous		4
4	Shale		6–8
5	Limestone		4
5	Limestone, massive, wavy-bedded		10
7	Covered	7	
8	Limestone, gray, massive, cherty; with Fusulina, to water level in creek	6	

Number 8 is the top of the Winterset; and Nos. 5 and 6 are number 85d; number 1 is correlated with Nos. 2-5 of the previous section.

In the SE. ¼ sec. 3, T. 62 N., R. 28 W., above number 1 of the last section, are the thin alternating layers of limestone and shale (Cherryvale) which reach to about the base of Bain's first section at Bethany (near the railway bridge north of the depot):

BAIN'S SECTION IN NORTHERN PART OF BETHANY.

Number.	Stratum.	Thickness.
		Feet.
1	Limestone, fragmental; loosely cemented (Drum)	6
2	Shale, green to drab, clayey; with thin bands of limestone	2
3	Shale, drab to black, clayey	2
4	Limestone, dark blue; in two ledges 9 and 3 inches thick, respectively	1
5	Shale, black	1
6	Shale, black to drab; with irregular nodular and thin layers of impure black limestone	6

It will thus be seen that there are exposed at Bethany three limestones, the Bethany Falls, Winterset and Drum, corresponding to Broadhead's numbers 78, 83-85a, and 87a, but the Hertha is below drainage.

A well drilled one-fourth mile south of center of sec. 9, T. 63 N., R. 28 W., on the flood-plain near the Falls, gave the following (driller's terminology):

LOG OF WELL AT BETHANY.

Stratum.	Thickness.	Depth.
	Feet.	*Feet.*
Soil	22	22
Falls limestone (Bethany Falls)	8	30
Shale; with some thin limestones (Ladore)	15	45
Limestone (Hertha)	6	51
Sandstone, hard, loose-grained (top of Pleasanton)	15	66
Sandstone, open, coarse-grained	28	94

Bain's[1] section in Decatur County, Iowa, included four limestones which he named, beginning at the base, the Fragmental, Earlham, Winterset, and De Kalb (or Fusulina). In attempting to correlate with the section at Bethany, Mo., he supposed the Winterset to be two beds instead of one, and with the Drum above and Bethany Falls below (four altogether) correlated them with the four in Decatur County, making the Bethany Falls at Bethany the equivalent of the "Fragmental" of Iowa. As the lithologic character of the two is not unlike, a correlation based on this character alone was seemingly correct.

The writer's correlation is shown in the following table:

CORRELATION OF BASAL MEMBERS OF KANSAS CITY FORMATION.

"DeKalb" ("Fusulina") limestone	=Drum limestone (No. 87a).
Winterset limestone	=Winterset (Nos. 83-85a).
"Earlham" limestone	=Bethany Falls (Nos. 78-80).
"Fragmental" limestone	=Hertha (No. 74).

Below the "Fragmental" of Iowa and the Hertha of Missouri there is a thin bed of coal, very persistent in Missouri, which gives additional support to the correlation.

The following section, taken down the branch in the NE. ¼ NW. ¼ sec. 2, T. 62 N., R. 28 W., is only approximate because of the great dip down stream, which exposed the lowest beds near the head of the branch:

[1]Op cit.

SECTION ABOUT THREE MILES SOUTHEAST OF BETHANY.

Number.	Stratum.	Thickness.
		Feet.
1	Shale, buff, brittle, calcareous, sandy	10±
2	Unexposed; probably about	20
3	Limestone, gray; in three beds with shale between (Raytown)	5+
4	Shale; clayey at top; black and slaty below (No. 95)	3
5	Limestone, gray (No. 92)	½
6	Unexposed (No. 91)	13+
7	Limestone, gray; rough on top (Cement City)	5
8	Shale, red	—

The failure of the Iola to outcrop in this section indicates that it is absent or very thin. The upper member of the section may belong to the Lansing formation.

SECTION AT CAINESVILLE.

Number.	Stratum.	Thickness.
		Feet.
1	Limestone, gray; fossiliferous; thin-bedded, irregular; top and bottom not exposed (Bethany Falls)	10
2	Covered	22
3	Limestone, gray; weathering brown; in two layers; the upper 18 and the lower 30 inches (Hertha)	4

No. 3, on a fresh fracture, is a fine-to coarse-grained crystalline limestone, with more *Composita subtilita* than any other fossil. In places it weathers light gray with a "fragmental" face, closely resembling the Bethany Falls limestone at Bethany.

Near Eagleville on Chain Creek the Drum is finely exposed and about four feet thick. East of Blythedale is an exposure of limestone thought to be the Cement City bed (No. 90). In the northeastern part of the county the limestones forming the base of the Missouri group are exposed along both sides of Grand River.

Mercer County.—The Kansas City formation outcrops at a number of places in Mercer County, chiefly along Grand River and East Muddy Creek. The Hertha limestone has also been found on Medicine Creek east of Ravanna. The Chanute shale is probably the highest bed in the county.

One of the best exposed sections of the basal limestones of the Kansas City occurring in north Missouri is at Princeton, where the following section was taken in the railroad cut south of town:

SECTION IN RAILROAD CUT SOUTH OF PRINCETON.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone, gray; weathers light buff; thin-bedded; fossiliferous (Bethany Falls)	14	
2	Shale, gray, clayey; grading into next below	2	1
3	Shale, black, slaty, bituminous	1	8
4	Limestone, dark gray; in two layers separated by shale	1	1
5	Shale, gray	9	8
6	Limestone, nodular, buff	1	
7	Shale, gray (base of Ladore)	5	
8	Limestone, gray; weathering brown; in two layers (Hertha)	{1	10
		{2	6
9	Shale, blue; with sandy limestone lens in places	4	6
10	Limestone, buff; varying in thickness; about	1	6
11	Covered; coal horizon	6	
12	Limestone, buff; weathering to nodules	1	
13	Shale, gray	20	

The following is a section of the beds above the Bethany Falls, which are well shown at the old crusher quarry south of Princeton:

SECTION AT OLD QUARRY THREE MILES SOUTH OF PRINCETON.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone, gray; cherty; thin wavy beds; buff shaly partings (Winterset)	12	
2	Shale; light at top; darker below; grading into next below	2	6
3	Shale, black, slaty, bituminous		10–14
4	Shale; dark at top; light below; grading into next below (base of Galesburg)	5	4
5	Shale; composed of loose, calcareous nodules	3	
6	Limestone, light gray, massive, oolitic (base of Bethany Falls)	7	7

The upper part of the Winterset is exposed across Grand River, about due west of this quarry, as follows:

SECTION IN THE NE. ¼ SE. ¼ SEC. 8, T. 64 N., R. 24 W.

Number.	Stratum.	Thickness
		Feet.
1	Limestone, light gray; composed mainly of Fusulina	6
2	Shale and thin limestones	8
3	Limestone, thin-bedded, cherty (No. 1 of last)	14

Fig. A. Hertha, Ladore and Bethany Falls members in railroad cut one mile south of Princeton.

Fig. B. Bethany Falls, Galesburg and Winterset members in quarry three miles south of Princeton.

This "Fusulina" limestone is to be correlated with that of the upper part of the Winterset at Bethany, the whole thickness of twenty-eight feet being Broadhead's numbers 83-85a.

The beds just below the Hertha are exposed 300 feet southwest of the northeast corner of sec. 7, T. 63 N., R. 24 W., as shown below:

SECTION WEST OF WELDON FORK NEAR MILL GROVE.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone (Hertha)	1 +	
2	Shale, light; with large concretions	3	6
3	Shale, black, slaty, bituminous	2	
4	Coal (Ovid)		7–8

A buff limestone (No. 12 of the Princeton section) usually occurs beneath the thin bed of fire clay that underlies this coal. This limestone varies from one to two feet in thickness.

Putnam, Sullivan, and Adair counties.—The area covered by the Missouri group in these counties is a matter of some doubt because of the extreme thickness of glacial drift, but that the group is represented in all three, by at least the Hertha limestone, is very probable. The Hertha was quarried only two miles west of the west line of Putnam County, and has been found farther east in the county on Chariton River drainage. The Hertha, Bethany Falls, and Winterset outcrop in Sullivan County in the syncline at Milan, and weathered fragments of the Hertha were found in Adair County on the high ridge lying east of Chariton River.

SECTION IN QUARRY IN SOUTHEAST PART OF MILAN.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone; unconsolidated nodules	1	10
2	Limestone, light gray; sub-oolitic; cross-bedded	5	8
3	Shale parting		2–4
4	Limestone, light-gray; unevenly bedded	3	
5	Shale, calcareous; very fossiliferous		8–10
6	Limestone like last	3	6
7	Limestone in bed of quarry	—	—

All this section is included in the Bethany Falls limestone and is continued downward in the railroad cut nearby as follows:

SECTION IN RAILROAD CUT SOUTH OF MILAN.

Number.	Stratum.	Thickness. Ft.	in.
1	Limestone (Bethany Falls)	—	—
2	Shale, blue, clayey	1	10
3	Shale, black, fissile, bituminous	1	6
4	Limestone, dark gray		4
5	Shale, drab	5	
6	Sandstone, yellow; thin even beds; calcareous; with worm burrows or fucoids on bedding planes	4	9
7	Shale, light drab, sandy (base of Ladore)	10	4
8	Limestone, gray; fine-grained; crystalline; fossiliferous; wavy-bedded (Hertha)	4	
9	Shale, light drab, clayey (top of Pleasanton)	2	5
10	Shale, bluish	3	
11	Shale, red		10
12	Shale, light	3	6
13	Shale; light; calcareous; resistant layer	1	
14	Shale, light drab; somewhat arenaceous and micaceous; with hard concretions	—	—

North of Milan the coal below the Hertha limestone is 14 inches thick with 25 feet of shale above.

In the northeastern part of the county (SE. ¼ NW. ¼ sec. 19, T. 64 N., R. 18 W.) are outcrops of the Hertha limestone and the underlying Ovid coal. The following is a detailed section of the Hertha at this place:

SECTION IN NORTHEASTERN PART OF SULLIVAN COUNTY.

Number.	Stratum.	Thickness. Ft.	in.
1	Limestone; composed mainly of shell fragments	1	
2	Shale, gray		2
3	Limestone; fossiliferous at top		3
4	Shale, gray		4
5	Limestone, gray; thin-bedded; cherty; fossiliferous	5	6
6	Shale, gray		8
7	Limestone, blue; thin-bedded; fossiliferous		6
8	Shale, dark (top of Pleasanton)	1 +	

The shale partings resemble those seen in the Hertha limestone northeast of Chillicothe, Livingston County.

In the northeast corner of sec. 27, T. 62 N., R. 16 W., Adair County, and at one or two places farther north, the Hertha limestone with the coal below it, is found as the highest consolidated rock of the divide east of Chariton River. As far as known, this is the most easterly exposure of the Missouri group.

LANSING FORMATION.

CHARACTERISTICS.

Beede and Rogers found the section from the Lane shale to the Oread limestone, inclusive, to constitute a faunal stage. According to Girty[1], the Lane, Weston, and Lawrence shale faunas are strikingly similar, being well marked off from the faunas of the shales and limestones both above and below, and, as the fauna of the Oread limestone is more closely related to that of the Stanton and Plattsburg than to any above, the interval from the Lane shale to the Oread limestone, inclusivee was classified as a faunal unit. The upper part of the unit had previously been designated the Douglas formation, a division it seems advisable to retain because the lower part is rendered more or less distinct lithologically by the greater proportion of limestone it contains. The beds included in the interval from the base of the Lane shale to the top of the Stanton limestone are, therefore, segregated and termed the Lansing formation. All its members are well exposed near Lansing, Kansas.

The thickness of the Lansing varies from 140 feet in Platte County to less than 100 feet along the west fork of Grand River. The upper half is chiefly limestone and the lower half shale and sandstone. The area of outcrop is shown on the State geologic map.

MEMBERS.

Lane shale member.—At the base of the Lansing is the Lane shale, 50 to 80 feet thick, thinning from southwest to northeast. The upper part is arenaceous and the lower part chiefly argillaceous. The two portions, over a large part of the area, are separated by the Farley limestone bed, ranging from a thin layer of calcareous shale to a bed of limestone 10 feet thick in an irregular manner and seemingly disappearing entirely to the northeast.

Plattsburg limestone member.—Above the Lane shale is the Plattsburg limestone. Its thickness is variabie but its other features fairly persistent. The maximum thickness is 20 feet in the southern part of the outcrop but to the north it becomes thinner. It is everywhere a blue, argillaceous limestone in the lower part, and cherty in the upper, weathering to a buff. The basal layer is more or less arenaceous and a marked pelecypod

[1]Evidence submitted to committee on nomenclature, U. S. Geol. Survey.

horizon. In its northernmost outcrop, it is commonly represented by fragments of brown, porous, weathered chert, or as a buff, brittle, thinly laminated, sandy limestone.

Vilas shale member.—Separating the two limestone members of the Lansing is the Vilas shale. In Platte County the Vilas is 20 feet thick, but to the northeast and east is only 3 or 4 feet. The composition varies from argillaceous or arenaceous shale to black, slaty shale with a thin coal seam in places. The bituminous phase may be found in the northern part of its outcrop.

Stanton limestone member.—At the top of the Lansing is the Stanton limestone member, composed of three limestone and two shale beds. The lower limestone is of a blue color and from a few inches to four feet thick. The lower shale bed is about five feet thick and contains, in most places, a layer of black slaty shale. The middle or main ledge of the Stanton is 15 feet thick, a gray, thin-bedded limestone with a 2-foot buff layer at the top. In a few places it is largely composed of Fusulina. The upper shale varies from one or two feet to twenty and, where thick, contains a layer of sandstone and green shale. The upper limestone is of a gray color, in two to four thin, even layers, in places separated by shale partings. Only the main ledge is generally seen where the Stanton caps escarpments.

REGIONAL VARIATION AND DETAILED SECTIONS.

Jackson County.—The highest indurated rocks in the county consist of the Lane shale and Plattsburg limestone members of the Lansing formation. They are not materially different from these members in Platte County. At the base of the Lane shale, however, there are 6 to 10 feet of arenaceous limestone separated from the Iola limestone by only six feet of sandy shale. This is apparently the Farley limestone bed, but, if so, it is much nearer the base of the Lane than at other places. However, it may be a local, lenticular limestone.

Clay and Platte counties.—The Lansing formation exhibits a remarkable regularity throughout these counties, the chief changes being in the thickness of the Farley bed and the Vilas shale, though the Plattsburg limestone also varies somewhat.

The part of the Lane shale below the Farley bed is a rather uniform bluish or greenish clay shale with no special characteristics, varying from 16 to 40 feet in thickness. At Parkville it is 16 feet thick. In one locality it was arenaceous. The Farley bed near Parkville is a coarse to oölitic, brownish-gray, resistant limestone. One-half mile above Parkville it occurs as one bed 8 feet thick. It is slightly ferruginous, quite compact and oölitic. In one place it is "cross-laminated." In many outcrops between Parkville and Waldron it is composed largely of Productus shells.

North of Waldron (center of the SE. ¼ sec. 14, T. 51 N., R. 35 W.) the following section of the Farley limestone bed was measured:

SECTION NORTH OF WALDRON.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone, dark blue; massive; coarse-grained; has prominent vertical joints	2	
2	Shale, dark drab, argillaceous	2	4
3	Limestone, dark blue; thin-bedded; coarse-grained	1	
4	Shale, drab; arenaceous; calcareous at top	4	
5	Limestone, blue; weathers buff; fine-grained; argillaceous; with wavy bedding planes	3	6

No. 1 of this section is the most uniform layer of the Farley, but it varies from a mere film to 5 feet in thickness. The beds below are extremely variable in thickness but the blue color and argillaceous character are persistent. In one or two places, there is a thin layer of pisolitic limestone above No. 1.

The part of the Lane shale above the Farley bed varies from 20 to 40 feet in thickness and contains, at most outcrops, a layer of sandstone. As with many other shale beds, the thickness is increased where the sandstone is present. In places it contains a red layer.

The Plattsburg is a bluish limestone, weathering buff, even-bedded in the lower part but more irregular in the upper. In many places it is cherty. The details are shown in the following section measured by Broadhead about one mile southwest of Waldron:

DETAILED SECTION OF PLATTSBURG LIMESTONE MEMBER ONE MILE SOUTH OF WALDRON.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone	9	
2	Shale		3
3	Limestone		3
4	Limestone		2
5	Limestone		6
6	Limestone		6

DETAILED SECTION OF PLATTSBURG LIMESTONE MEMBER ONE MILE SOUTH OF WALDRON—Continued.

Number.	Stratum.	Thickness. Ft.	in.
7	Limestone	1	8
8	Shale		4
9	Limestone		10
10	Shale		6
11	Limestone		10
12	Shale		3
13	Limestone		10
14	Shale		3

Along Missouri River the Vilas shale is 17 to 20 feet thick, is argillaceous, and, in places, has a reddish cast. The Stanton limestone in this region varies but little from that shown in the generalized section near the beginning of this chapter.

The following is a typical section of the Plattsburg, Vilas, and Stanton members in eastern Platte and Clay counties:

TYPICAL SECTION OF UPPER HALF OF THE LANSING FORMATION IN EASTERN PLATTE AND CLAY COUNTIES.

Number.	Stratum.	Thickness. Ft.	in.
1	Limestone, gray; in thin layers (No. 115)		4
2	Limestone, gray; in one bed (No. 115)	1	
3	Shale, gray (No. 115)		7
4	Limestone, blue, argillaceous (No. 115)		9
5	Shale, greenish and sandy above; argillaceous below (No. 114)	6	8
6	Limestone, buff (No. 113)	2	
7	Limestone, gray; thin-bedded; with buff, shaly partings (No. 112)	13	
8	Shale; slaty in lower half (No. 111)	5	
9	Limestone, blue; even-bedded; in 4 or more layers (No. 110—base of Stanton limestone)	3	
10	Shale, blue, sandy (No. 109—Vilas shale)	4	6
11	Limestone, banded gray; in thin wavy beds; weathering buff and sandy (top of Plattsburg)	1	4
12	Shale, buff; with layers and nodules of limestone	2	7
13	Limestone, nodular		4–5
14	Shale, buff		8
15	Limestone, bluish-gray	2	6
16	Shale		1
17	Limestone, bluish-gray	6	6
18	Shale		2
19	Limestone, bluish-gray	1	8
20	Shale, blue		8
21	Limestone, buff, cellular		9
22	Limestone, gray		6
23	Shale, dark-blue, almost black	1	
24	Shale; with layers and nodules of limestone	1	4
25	Limestone, blue (base of Plattsburg)	4	4

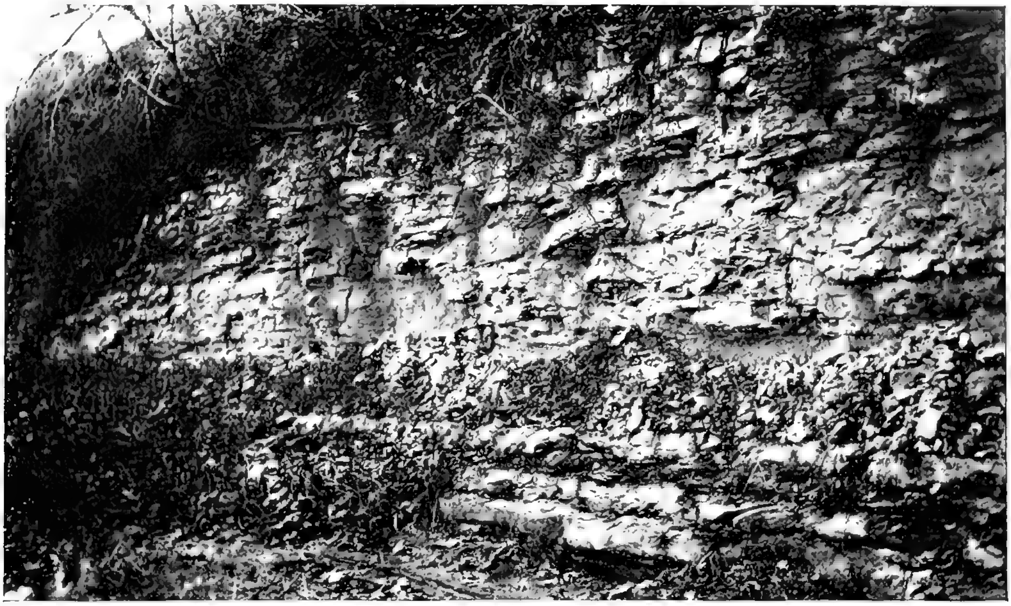

Fig. A. Plattsburg limestone near Smithville.

Fig. B. Stanton limestone (lower and main ledges) near Plattsburg.

To the southeast, the shale (No. 114) increases to 20 feet in places and contains a layer of sandstone, but is greenish at the top and bottom.

In the northeastern part of Clay County, part of the Lansing is exposed near Holt. The following section was taken north of the town:

SECTION NEAR HOLT.

Number.	Stratum.			Thickness.	
				Ft.	*in.*
1	Limestone (Plattsburg), blue to gray; weathering buff; hard to shelly; cherty at top; shows the following beds:	*Ft.*	*in.*		
	Limestone, thick-bedded, cherty	5			
	Limestone, thin-bedded	6	6		
	Shale	1			
	Limestone	2			
	Shale		2		
	Limestone, shelly; grading to shale below	1	6	16	2
2	Sandstone and shale (Lane), shale at top; sandstone varies from hard to soft, red to white; is ripple-marked and cross-bedded, massive or thin-bedded, micaceous; in the middle is a 9-10-inch layer of blue limestone (Farley)			65–70	
3	Limestone (Iola)			—	—

Ray County.—The upland at Lawson probably contains part or all of the Lansing formation but aside from a few feet of the basal Lane shale, no outcrops of it were seen.

Buchanan County.—In the southeastern corner of the county along Platte River there are outcrops of the upper part of the Lansing formation. Two miles south of Agency, on the east side of Platte River, the following is exposed:

SECTION TWO MILES SOUTH OF AGENCY.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Shale (base of Weston)	—	—
2	Limestone, gray; in two beds (top of Stanton)		10
3	Shale	3	9
4	Limestone, dark, somewhat sandy; 1 foot to	1	4
5	Shale	5	
6	Limestone, gray, thin-bedded; top very uneven (No. 112)	16	
7	Shale, lower 1½ feet dark to black (No. 111)	3	6
8	Limestone; in three beds (No. 110—base of Stanton)	1	5
9	Shale, and yellow, nodular limestone	1	
10	Limestone, finely striped parallel to bedding planes		4
11	Shale and thin beds of limestone	1	2
12	Limestone		8

SECTION TWO MILES SOUTH OF AGENCY—Continued.

Number	Stratum.	Thickness.	
		Ft.	in.
13	Shale		10
14	Limestone, buff, argillaceous; thin-bedded; grading into shale above	2	2
15	Limestone, gray; even-bedded; weathering to fragments size of a hand; to water level	4	

Numbers 14 and 15 are typical Plattsburg limestone, though Nos. 10 to 13 may be included.

Clinton County.—The outcropping rocks over a large part of Clinton County belong to the Lansing formation. At Plattsburg, the locality which Broadhead took as the type of the Plattsburg limestone, the following section was measured:

SECTION SOUTHEAST OF PLATTSBURG.

Number.	Stratum.		Thickness.
			Feet.
1	Limestone, buff, argillaceous (No. 113)		1
2	Limestone, light gray; thin-bedded; with buff, wavy partings (No. 112)		11
3	Covered slope wih black shale scattered over it (Nos. 109-111)		9
4	Limestone, dark blue; thin-bedded to finely laminated; argillaceous	(No. 108)	5
5	Limestone, buff, shelly; with calcite streaks; grades into above		6

The lower portion of the Plattsburg outcrops a short distance to the north. The section here is as follows:

LOWER PORTION OF PLATTSBURG LIMESTONE MEMBER NEAR PLATTSBURG.

Number.	Stratum.	Thickness.	
		Ft.	in.
1	Limestone, white and buff; even-bedded, argillaceous	6	
2	Shale, blue, clayey	1	3
3	Limestone, light buff		9
4	Shale, dark; calcareous at base	1	
5	Limestone, buff, shaly		5
6	Shale		1
7	Limestone, buff, shaly		4
8	Limestone, buff, shaly		8
9	Shale; blue to water	1	6

This section reaches to the lower part of the first section under "Clinton County," and with Nos. 4 and 5 of that, constitutes the Plattsburg limestone.

The beds between Nos. 2 and 4 of the first section at Plattsburg are seen in the northeast corner of sec. 24, T. 55 N., R. 32 W., as follows:

SECTION IN THE NORTHEAST CORNER OF SEC. 24, T. 55 N., R. 32 W.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone (No. 112)	—	—
2	Shale; black in middle (No. 111)	5	
3	Limestone, gray; resistent (No. 110)	1	3
4	Shale, drab (No. 109)	3	
5	Limestone (No. 108)	—	—

The upper Stanton (Broadhead's number 115), is seen at the head of the small branch in the SW. ¼ sec. 30, T. 55 N., R. 31 W., as shown below:

SECTION IN THE SW. ¼, SEC. 30, T. 55 N., R. 31 W.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Shale, argillaceous; with brown ferruginous concretions	—	—
2	Limestone, very shelly; weathers to small pieces		3
3	Limestone, gray		4–6
4	Limestone, gray		10
5	Shale to No. 113	3±	

The lowest limestone seen in this vicinity is the Farley limestone bed, which outcrops at the ford in the stream at the northeast corner of sec. 30, T. 55 N., R. 31 W.

Between Plattsburg and the outcrops along Missouri and Platte rivers, there is very little change in the Plattsburg, Vilas, and Stanton beds as shown on outcrop, except a thickening of the Vilas shale to the south and west.

Although Lathrop is situated on a high divide at an altitude of 1,060 feet, the Plattsburg limestone is the highest rock exposed. The following section was taken on the head waters of Shoal Creek from where it crosses the line between sections 19 and 30 to one-eighth mile north of line between sections 18 and 19, T. 55 N., R. 30 W.:

SECTION ON SHOAL CREEK EAST OF LATHROP.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Chert, black; weathering to blocks	1½–2	
2	Limestone, even bed		3
3	Limestone, gray; thin-bedded; buff on partings	5	
4	Shale, drab	1	6
5	Limestone		10–12
6	Shale, drab		11
7	Limestone, gray; weathers buff; shaly	2	
8	Shale and shaly limestone	1	
9	Limestone, thick- to thin-bedded	3 +	

Below this, drift fills the bed of the stream and there are no outcrops for some distance. The entire section belongs to the Plattsburg (No. 108).

The next outcrop seen was on the east bluff of Shoal Creek in sec. 32, T. 56 N., R. 30 W.:

SECTION ON SHOAL CREEK ABOUT FOUR MILES NORTH OF LATHROP.

Number.	Stratum.	Thickness.
		Feet.
1	Shale, buff; resistant; calcareous or sandy; brittle; in places hardening into a very firm, blue, calcareous sandstone (base of Plattsburg)	15
2	Sandstone, shaly and calcareous	5
3	Covered, argillaceous and sandy shale in places	50
4	Calcareous sandstone in bed of creek	—

No. 1 of this section is doubtfully referred to the lower part of the Plattsburg. The remainder belongs to the Lane shale.

The northernmost outcrop which can be definitely correlated with the Farley limestone bed is on the south side of the creek, on the road in the eastern part of sec. 14, T. 56 N., R. 30 W.:

SECTION SOUTH OF CAMERON.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone (Plattsburg)	—	—
2	Covered, shale and sandstone	20–25	
3	Limestone; poor outcrop	2	
4	Shale and limestone; poor outcrop	4	6
5	Limestone, blue, resistant, oolitic, sandy (Farley)	3	
6	Shale, sandy	—	—

Caldwell County.—The Lansing is the highest indurated rock formation in the west-central and northwestern portions of the county. Both of the limestone members at the top of the formation outcrop west of Kidder. The section closely resembles that at Winston, Daviess County, to which the reader is referred.

Holt and Andrew counties.—The Lansing formation does not outcrop in these counties, though the deep drilling at Forest City shows the nature of the formation.

De Kalb County.—Grindstone Creek and its tributaries in the vicinity of Maysville, Weatherby, and Fairport show small sections of the Lansing formation. The following section was taken near Maysville in the northeast corner of sec. 2, T. 58 N., R. 31 W., on the east bank of Lost Creek:

SECTION NEAR MAYSVILLE.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Shale, buff, sandy, brittle; calcareous; weathers reddish brown	3	
2	Limestone, gray, or slaty blue; thin-bedded, cherty; chert weathers out into brown porous masses	3	6
3	Shale, buff, calcareous	2	
4	Limestone, gray, resistant; heavy-bedded; wavy bedding planes	3	3
5	Shale, blue, clayey	1	
6	Shale, buff, calcareous	1	4
7	Limestone, buff, argillaceous		4
8	Shale, drab, clayey	2	
9	Limestone, buff, argillaceous		7
10	Shale, drab, clayey	3	
11	Limestone, buff, shaly, resistant, brittle; grades into next above	1	
12	Shale; grades into soft drab to black fissile bituminous shale	2	3
13	Shale, blackish, sandy; resistant layer	2	
14	Shale, blue, sandy, micaceous	17	

Numbers 12-14 are correlated with the Lane shale; all above these with the Plattsburg limestone.

The Plattsburg limestone is shown in the following section, taken by Buehler[1] in a quarry near here:

[1]Buckley, E. R., and Buehler, H. A., The quarrying industry of Missouri: Missouri Bureau of Geology and Mines, vol. 2, 2nd series, p. 245, 1904.

BUEHLER'S SECTION NEAR MAYSVILLE.

Number.	Stratum.	Thickness. Ft.	in.
1	Stripping; clay and soil		2
2	Limestone, buff colored, fine-grained, compact; contains calcite geodes	1	2
3	Limestone, buff colored, fine-grained; splits into two beds; weathers rapidly		10
4	Shale, white		6
5	Limestone, yellowish-brown, granular, soft; used for well rock		4
6	Limestone, blue, colored buff along bedding planes, fine-grained, fossiliferous; contains small calcite geodes		8
7	Limestone, like above		8
8	Limestone, dark blue, finely crystalline; contains calcite geodes	1	
9	Limestone, blue, fine-grained		8

At Weatherby the Plattsburg limestone is poorly represented. Following is a section in the road in the middle of sec. 27, T. 59 N., R. 30 W., south of the Rock Island Railroad:

SECTION NEAR WEATHERBY.

Number.	Stratum.	Thickness. Ft.	in.
1	Limestone, brown; very arenaceous; weathered to porous fragments	3	
2	Limestone		3
3	Shale	1	
4	Limestone (base of Plattsburg)		4
5	Covered, shale at bottom; probably all shale or shaly sandstone (Lane)	35	

The Stanton limestone was not exposed at any place visited by the writer, but undoubtedly occurs in the northern and western parts of the county.

Daviess County.—The best outcrops of the Lansing formation in the county are found west of Winston. A typical section is as follows:

TYPICAL SECTION NEAR WINSTON.

Number.	Stratum.	Thickness. Ft.	in.
1	Limestone, gray to buff; cherty in places	12–16	
2	Shale, dark at top, yellow at bottom where it contains small calcareous concretions	3	
3	Limestone; heavy with siderite (base of Stanton)		2–4

TYPICAL SECTION NEAR WINSTON—Continued.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
4	Shale; calcareous or with nodular limestone	3	
5	Coal; represented in some sections by 1 ft. 9 in. black, slaty, bituminous shale		1–4
6	Shale, sandy (base of Vilas)	2	
7	Limestone, buff, shaly	3	
8	Limestone, blue	3	
9	Limestone, blue, resistant	1	2
10	Shale	3	
11	Limestone, shaly (base of Plattsburg)	1	6
12	Shale and sandstone; becomes more arenaceous toward bottom; locally contains a thin limestone (Farley) near middle (Lane)	50	
13	Kansas City formation	—	—

In the northwestern corner of the county the tops of the highest hills show fragments of a brown, porous, arenaceous material which is thought to be weathered chert from the Plattsburg limestone. It resembles the tripoli of Newton County, Mo., in texture though not in color. Its stratigraphic relations have never been clearly ascertained. North of Pattonsburg (sec. 21, T. 61 N., R. 29 W.) the fragments were found 50 feet above the Drum limestone. Northwest, along the Wabash Railroad tracks, the fragments were 30 feet above the Raytown limestone bed. About four miles northwest of Pattonsburg the following section was taken south of the tracks:

SECTION FOUR MILES NORTHWEST OF PATTONSBURG.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Shale, buff, brittle, sandy	1	
2	Shale, dark blue; argillaceous at base; lighter and arenaceous toward top; one foot from top is a thin layer of sandstone	11	
3	Limestone, blue, shelly, fossiliferous		8–12
4	Limestone, buff, gray at top, brittle; sandy; thin-bedded; with layers of impure chert	5	
5	Shale, blue	1	
6	Limestone, like No. 4	1	
7	Shale, blue, argillaceous; contains septarian concretions and large irregular masses of limestone	10	
8	Limestone, dark gray, impure, fossiliferous		8
9	Shale, blue, argillaceous	10	

The chert in No. 4 may weather into the brown tripoli mentioned above.

Atchison and Nodaway counties.—The Lansing formation in these counties is concealed by later formations and is known only from the Maryville drill record (see p. 239).

Worth County.—Outcrops correlated with the upper part of the Lansing formation are found along Grand River from Denver north. On the banks of Grand River at Denver, near the sawmill, the following section was observed:

SECTION AT DENVER.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone, gray, thin-bedded		8
2	Limestone, gray, fine-grained, cherty, heavy-bedded; weathers with a buff tinge	2	4
3	Limestone, gray, thin-bedded		6
4	Covered; probably limestone	2	6
5	Limestone, gray; weathers buff; even layer		7
6	Shale; at top buff, calcareous; below this a hard black layer; black and drab at base	1	10
7	Limestone, blue, fine-grained; even layer		7
8	Shale, drab		1
9	Limestone, shaly; very fossiliferous		1
10	Shale, dark drab; to water		4

Number 7 is correlated with the lower part of the Stanton and Nos. 1-5 with the main ledge of that member. The shale, No. 6, contains *Chonetes granulifer* and otherwise resembles the shale at this horizon in other localities farther south.

The following section was measured at the old mill site near Denver:

SECTION NEAR DENVER.

Number.	Stratum.	Thickness.
		Feet.
1	Limestone, buff, very shaly	1
2	Limestone, gray; 6-inch beds	2
3	Concealed	11
4	Limestone, gray; with worm burrows or fucoids	1

The lowest limestone in this section is probably Broadhead's number 115. The beds in the two foregoing sections are also seen on the east bluff of Grand River at the bridge, one and a half miles north of Denver.

Gentry County.—The southeastern corner of Gentry County is the northernmost locality in the State in which there were observed sections of the Lansing formation approaching completeness. A section taken near the center of sec. 35, T. 62 N., R. 31 W., where the road crosses the branch, shows:

SECTION NEAR GENTRYVILLE.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone, buff, fine-grained; one foot to	1	3
2	Covered	2	
3	Limestone, buff	3	
4	Covered	12	
5	Limestone, buff		3–4
6	Limestone, gray, impure; one foot to	1	2
7	Shale, a mere film to	1	2
8	Shale, buff, calcareous, brittle	1	3
9	Covered, apparently all shale	60	
10	Limestone, gray, fossiliferous; in two beds in bottom of creek	1	2

No. 10 of the above is the top of the Iola, the heavy shale is the Lane, and the beds above belong to the Plattsburg, Vilas and Stanton.

Near the south side of sec. 23, T. 62 N., R. 31 W., north of where the road turns to the south, are:

SECTION NEAR GENTRYVILLE.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone, gray; composed of fragmentary fossils	1	
2	Slope with outcrop of black shale	16	
3	Limestone, buff; very fine-grained; with interbedded shale	2	2
4	Limestone; several thin layers with interbedded shale		8
5	Covered	19	
6	Limestone, uniform bed		3
7	Shale		4–6
8	Limestone, nodular, impure	1	6

Numbers 5-8 belong to the upper part of the Lane shale; Nos. 3-4 to the Plattsburg; and No. 1 probably to the Stanton.

Near the south side of sec. 26, T. 62 N., R. 31 W., up south bank of creek northwest of ford, are exposed:

SECTION NEAR GENTRYVILLE.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone, gray, thin-bedded	6	
2	Slope	31	
3	Limestone, buff, even-layer; fine-grained	1	
4	Shale and thin limestones		8
5	Limestone, buff; shaly in places	3	
6	Covered	14	
7	Shale, buff, calcareous, sandy, brittle	5	9
8	Shale, drab; to creek	12	

Number 1 is possibly the Stanton but may be the Iatan member of the Douglas formation; Nos. 3-8 are probably the Plattsburg to Stanton.

On the road near the southeast corner of sec. 35, T. 62 N., R. 31 W., are:

SECTION NEAR GENTRYVILLE

Number.	Stratum.	Thickness.
		Feet.
1	Slope with scattered fragments of limestone	15
2	Limestone, blue	1
3	Shale, drab	9
4	Limestone, gray; thin-bedded; fine-grained; top of each layer covered with what appear to be worm burrows	13
5	Slope with outcrop of black shale	10
6	Limestone, gray, weathers buff; fine-grained; slope with fragments of brittle, buff, calcareous shale	3

Number 4 is probably to be correlated with the Stanton and No. 6 with the Plattsburg.

The two following sections are both in the Lane shale, below the Plattsburg limestone:

SECTION AT NORTHEAST CORNER OF SEC. 30, T. 62 N., R. 30 W.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Slope with fragments of buff, calcareous shale and weathered porous masses of calcareous sandstone	—	—
2	Shale, drab, sandy, micaceous	20	
3	Limestone, gray, fossiliferous; thickens to four feet 50 feet to south		6
4	Shale	8	
5	Limestone, gray, fossiliferous		6–12
6	Shale, bright blue	5	

SECTION SOUTH OF CREEK ON EAST SIDE OF SEC. 18, T. 62 N., R. 30 W.

Number	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone, gray, fossiliferous		6
2	Shale, drab	2	6
2	Shale, buff, calcareous, brittle, micaceous	4	
4	Shale, calcareous; grades into above	2	
5	Limestone; two thin layers with interbedded shale	1	2
6	Shale, blue to dark; with two very thin layers of limestone	7	8

No outcrops could be found on Grand River near Darlington, probably because a deeply buried preglacial channel exists at that place.

Harrison County.—Broadhead reports an outcrop of the Plattsburg limestone in the northeastern corner of the county, but the writer failed to find it. It is probable that the whole thickness of the Lansing formation occurs in the western part of the county but is covered by drift. In the section south of Bethany (page 151) the upper bed may be the Plattsburg. It resembles the rock doubtfully referred to the Plattsburg in Daviess and Gentry counties.

DOUGLAS FORMATION.

CHARACTERISTICS.

The Douglas is essentially a shale and sandstone formation, though the Oread member at the top is one of the thickest limestones in the Pennsylvanian. The variation in thickness is shown by the following measurements:

Platte County	300 feet.
Forest City drilling	276 "
Maryville drilling	238 "
Hopkins drilling	200 "

The strata below the Oread member are rather irregular because of the lenticular nature of the limestones and the presence, in certain localities, of basin or channel-like sandstone deposits seemingly unconformable at the base.

Coal has been found at two or more horizons, at one of which is the thickest coal bed in the Missouri group. The stratigraphy, on the whole, bears a close resemblance to that of the Cherokee shale and Pleasanton formation.

MEMBERS.

Weston shale member.—The basal member of the Douglas is the Weston shale, which is argillaceous in most places and varies from 60 to 100 feet in thickness. Its soft nature causes the overlying Iatan limestone to form an escarpmant where not concealed by glacial drift.

Iatan limestone member.—The Iatan member is a dark to light gray, mottled limestone with large red blotches in places on the weathered surface. The most usual mode of weathering gives it a corrugated appearance. It appears as a thin and irregularly bedded or massive limestone. The thickness of the Iatan varies from 2 to 22 feet, but, except in two areas, it is present at its horizon both in outcrops and drillings. The Forest City drilling indicates that it was never deposited in that region and in southern Platte County it appears to have been removed by erosion preceding unconformity.

Lawrence shale member.—The Lawrence shale consists of 130 to 200 feet of shale and sandstone with two or three coal seams and a limestone, the Amazonia limestone bed, which in places attains a thickness of 16 feet. The thinning of the Lawrence shale is from south to north as is the case with most of the other thick shale members. The upper 10 to 20 feet contain in practically all outcrops and drill records a prominent bed of red shale.

The Amazonia bed is 25 to 100 feet below the top of the Lawrence, the interval decreasing at a fairly regular rate from south to north along Missouri River. Above the Amazonia the Lawrence is prevailingly arenaceous and below argillaceous, but this does not hold true in all sections. The shale above the Amazonia contains a coal seam and another is found 10 to 20 feet from the base of the Lawrence, but both are non-persistent. The latter is overlain by an impure, very fossiliferous limestone, and underlain, in many places, by red and blue shale.

The channel sandstone which outcrops in southern Platte and southwestern Clay counties is an unconformable bed that appears to be of Lawrence age. This sandstone is the highest indurated formation in most of its area of outcrop but its age seems to be fairly well established. Drillings at Valley Falls and Atchison, Kans.[1], show the sandstone to be overlain by the

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[1]Haworth, E., Special report on oil and gas: Kansas Univ. Geol. Survey, vol. 9, plates CII and CVI, 1908.

Fig. A. Conglomerate resting on Stanton limestone near Nashua.

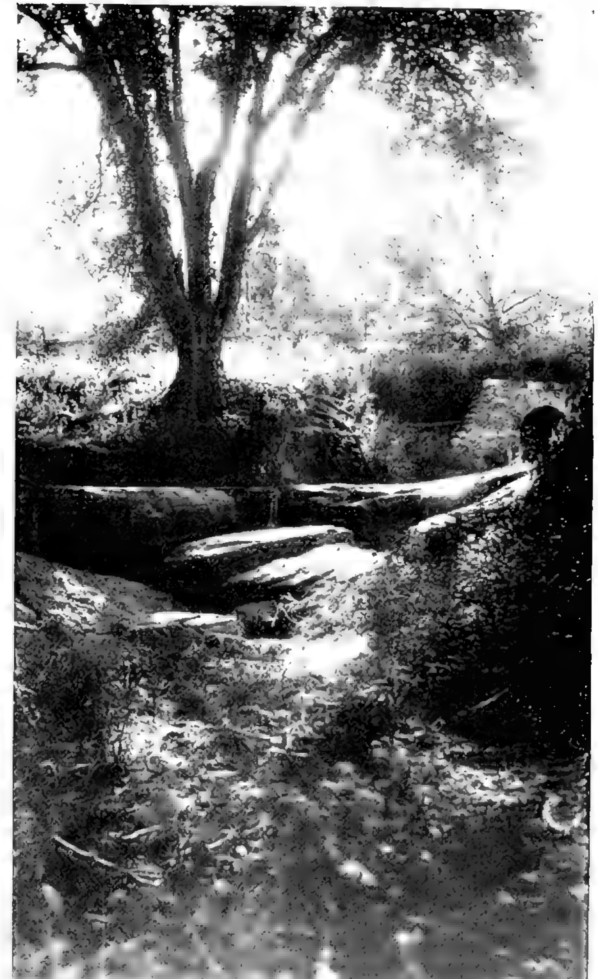


Fig. B. Conglomerate one mile north of East Leavenworth.

Oread limestone and there is little doubt but that it passes below the Oread escarpment at Leavenworth, Kans., all of which occurrences indicate its age to be Lawrence. In much of its outcrop it replaees the two lower members of the Douglas. It is described more fully below.

Oread limestone member.—The Oread limestone consists of four beds of limestone separated by three beds of shale. The lower limestone is of a blue or gray color, 3 to 8 feet thick, weathering buff or gray. Above it is 10 to 20 feet of blue or drab, sandy shale or red clay. The middle limestone is a dense, dark-gray, even-bedded rock, in one or two layers, jointed perpendicularly, and about two feet thick. The shale above is about five feet thick and is usually, in part, black and slaty. The upper limestone varies from 17 to 35 feet in thickness, is thin-bedded, contains cherty layeis, and has buff, wavy, shaly partings. It is characterized by the abundance of Fusulina. Above the upper limestone, and commonly separated from it by a thin film to 14 feet (average about three feet) of blue or gray clay shale, is the so-called "Waverly flagging," consisting of three feet or more of gray, somewhat oölitic limestone with a splintery fracture. The Oread limestone forms one of the best marked escarpments of the Pennsylvanian, where not covered by thick glacial drift.

REGIONAL VARIATION AND DETAILED SECTIONS.

Platte and Clay counties.—The entire thickness of the Douglas formation is exposed in Platte County. North of the latitude of East Leavenworth the base of the formation is the Weston shale, overlain by the Iatan lımestone. South of East Leavenworth the horizon of the formation is represented by a channel sandstone, of Lawrence age, and its accompanying conglomerate. This deposit extends from Missouri River across Platte County and four miles into Clay County, forming the divide between the Platte and Missouri rivers. North of its outcrop no trace of it could be found; farther south, it has been removed by erosion, if ever deposited. It has a maximum thickness of nearly one hundred feet and is accompanied locally by a basal conglomerate composed mainly of fragments of limestone in a calcareous cement. It is unconformable on the underlying rocks. In places the sandstone and the locally developed basal conglomerate have been found resting on some part of the Stanton limestone, well below the top of that member; in others only the upper part of the Weston shale had been removed before the deposition of the sandstone. In most of Platte and Clay counties the sandstone rests on the upper layer of the Stanton limestone.

Near the contact with the underlying limestone there are, locally, concretionary forms of white, vitreous, calcareous sandstone and bands of material containing much siderite. Coal has also been found near the base. The main body of the sandstone varies from a massive to a thin-bedded structure, contains beds of clay shale, is cross-bedded, and has ripple marks.

The best outcrops of the basal conglomerate are at East Leavenworth, north of the store, where it is eight and one-half feet thick, and in the northern part of sec. 31, T. 52 N., R. 32 W., where it is about five feet thick. It is cross-bedded in both places. The best outcrop of the coal accompanying the sandstone was seen near the southwest corner of sec. 36, T. 52 N., R. 34 W., where the following section was measured:

SECTION SOUTHEAST OF FARLEY.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Sandstone	—	—
2	Shale, arenaceous; with thin layers of sandstone	15	
3	Coal, poor		8
4	Shale, black, bituminous; grades into next below		10
5	Shale, drab	4	6
6	Sandstone, calcareous; firmly cemented		6–11
7	Shale, drab, clayey	1	6
8	Shale, drab, clayey; more resistant than last	1	6
9	Sandstone; probably	20	

The conformable members of the Douglas outcrop north of the sandstone area and do not occur in Clay County. The Weston member is a clay shale with no sandstone. It contains the concentrically-banded iron concretions characteristic of many shale beds. It is about 60 feet thick near the southern limit of its area, but increases to 80 or 90 feet near the north line of the county. The Iatan limestone above is gray with red blotches, thick-bedded in fresh faces but weathering into thin irregular beds having a brecciated appearance due to the leaching of the crystalline calcite of the fossils. Its thickness varies from 8 or 10 feet to 22 feet just south of Iatan. The following section was measured one-half mile northwest of the Weston depot:

Fig. A. Sandstone near Linkville, Platte County. Shows concretions at base.

Fig. B. Iatan limestone in railroad cut at Iatan.

SECTION ONE-HALF MILE NORTHWEST OF WESTON.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Shale, calcareous; extremely fossiliferous	2	
2	Shale; drab at top and bottom; buff in middle	10	
3	Limestone, black, bituminous; shaly and sandy		6
4	Shale and clay; black at top, grades down through clay to drab shale (base of Lawrence)	6	4
5	Limestone, gray, heavy-bedded (Iatan)	12	6
6	Slope, shaly (Weston)	70	
7	Limestone (top of Stanton)	2	

The Iatan dips below the bottoms one and one-half miles northwest of Iatan.

The Lawrence shale member in Platte County varies from 175 to 200 feet. It is composed of clay, sandy shale, and sandstone. Near the top is a persistent layer of red shale and near the middle a thin bed of crystalline limestone, probably the southern extension of the Amazonia limestone bed. Near the base is a coal horizon (in No. 4 of preceding section) at which there is a maximum of fourteen inches of rather poor coal. Outcrops of the Lawrence shale are poor and no detailed section could be obtained in this county.

The upper member of the Douglas, the Oread limestone, is typically developed in Platte County and closely follows the description given in the generalized section. The so-called "Waverly flagging" above the upper limestone of the Oread member is about four feet thick and at the top has two or three inches of calcite with a peculiar vertical cleavage ("cone-in-cone.")

Buchanan and Clinton counties.—The whole of the Douglas formation outcrops in Buchanan County and the two lower members occur in the western part of Clinton County. The section closely corresponds to that of Platte County but differs in the absence of the channel sandstone and in the presence of the typically developed Amazonia limestone bed. Other changes, chiefly in thickness, also take place. The lowest part of the section is exposed on Platte River south of Agency, where the section is as follows:

SECTION ON PLATTE RIVER SOUTH OF AGENCY.

Number.	Stratum.		Thickness.	
			Ft.	*in.*
1	Limestone, thin-bedded; contains Fusulina.....	(Iatan)		8
2	Shale....................................	(Iatan)		3
3	Limestone, gray; weathers to a blocky form.....	(Iatan)	4	2
4	Shale (Weston).....................................		100	
5	Limestone (Stanton).................................		—	—

The areal extent of these members in Clinton county is unknown, but one or both are probably present.

In the southwestern corner of the county, at Tank (now Armour) Broadhead found: "2 feet dark colored, evenly bedded, ferruginous limestone, rough fracture, weathers red, upper and lower bed 9 inches thick with a shale band beneath the upper layer (number 128)." This is 15 feet above the railroad and 116 feet below the upper limestone of the Oread. Broadhead called this number 128, but on page 122 he says "number 128 was only positively recognized near St. Joseph." This limestone was traced from its first appearance to St. Joseph and found to be the Amazonia bed (Broadhead's number 137). It thickens to the north and also changes greatly in its general appearance. At Rushville it is shown in the following section:

SECTION AT RUSHVILLE.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone, blue and buff; with buff shaly partings; cherty (upper limestone of Oread member)..................	18	
2	Covered, about.......................................	35	
3	Limestone, buff, shaly (lower limestone of Oread member)..	3	
4	Covered, about.......................................	60	
5	Limestone, gray, even-bedded, fine-grained (Amazonia)....	3	8
6	Shale, blue, clayey..................................	—	—

The shale above the Amazonia is sandy in most outcrops and that below clayey. Between Rushville and St. Joseph the Amazonia is about 100 feet below the upper limestone of the Oread member.

The rise in the strata above Rushville exposes the following section in the NW. ¼ sec. 5, T. 55 N., R. 36 W.:

SECTION NORTHEAST OF RUSHVILLE.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone (No. 143) (lower limestone of Oread member) ..	—	—
2	Covered; slope and shale	40	
3	Coal		5
4	Shale, blue; with occasional layers of micaceous sandstone	10	
5	Sandstone, blue; usually firmly cemented but shaly in places	5	
6	Shale	6	
7	Limestone, gray, even-bedded (Amazonia)	5	
8	Shale, blue, clayey	7	
9	Covered to bottom	40	

The ravine in the northeastern corner of sec. 1, T. 55 N., R. 37 W., shows:

SECTION ON BLUFF, EAST OF HALL'S STATION.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone, buff; thin-bedded; cherty; wavy partings (upper limestone of Oread member)	12	
2	Shale; black and bituminous in lower part; blue and argillaceous in upper	5	10
3	Limestone, gray massive, (middle limestone of Oread member)	1	9
4	Covered	25	6
5	Limestone, buff (lower limestone of Oread member)	7	
6	Shale, blue	8	
7	Covered	57	
8	Limestone, gray, even-bedded (Amazonia)	5	

One-half mile north of this place the Amazonia is seven feet thick, the upper two feet shaly, the lower five feet thin and evenly bedded, and the whole weathering buff.

The section at Atchison, Kans.,[1] is inserted here to show the relation of the coal worked near Atchison to that on the Missouri side of the river. It also shows the beds above the Oread which occur in the southern part of Buchanan County but are not well exposed. The correlations in parentheses are the writer's:

[1]Kneer, E. B., A geologic section from Atchison to Barnes, etc.: Kansas Univ. Geol. Survey, vol. 1, pp. 140-141, 1896.

SECTION AT ATCHISON, KANSAS.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Drift	50–60	
2	Shale	—	—
3	Limestone, weathered	2±	
4	Clay	2	
5	Limestone	2	
6	Shale, black, slippery	2	
7	Limestone; rich in Fusulina; darker than the following, yet lighter than most of the Atchison limestones	2	
8	Limestone; very light in color and much resembling Cottonwood Falls rock, but not porous	2	
9	Shale	5	
10	Limestone; very good for building and mostly used for such purpose	6	
11	Shale	2	
12	Coal		4–8
13	Shale	4–10	
14	Sandstone; runs into shale in places and is common in all bluffs	6	
15	Shale; use extensively for the manufacture of vitrified brick	20–25	
16	Limestone, hard compact, broken at regular intervals into large monoliths, very similar to No. 22 in appearance	2	
17	Shale (base of Shawnee formation)	5	
18	Limestone ("Waverly flagging" in Oread member)	6	
19	Shale	4–6	
20	Limestone; more or less flinty; of little or no value for building purposes; used extensively for railroad ballast (upper limestone of Oread member)	21	
21	Shale, laminated; containing more or less pyrite nodules	3–4	
22	Limestone, hard, firm; breaks off in immense blocks, and is conspicuous in all bluffs (middle limestone of Oread member)	1	9
23	Shale	9	
24	Limestone (lower limestone of Oread member)	10	
25	Shale	25	
26	Coal; worked at the Donald and Ada mines two miles south of Atchison		16–18
27	Shale	30	

The section above the Douglas formation is discussed under Shawnee formation. It will be noticed that there is no limestone at the horizon of the Amazonia bed, the same being very thin on the Missouri side of the river opposite this place.

Up the river from Rushville the Iatan appears in the southeast corner of sec. 14, T. 56 N., R. 36 W. as three feet four inches of compact, gray limestone.

A short distance north of Rushville the Amazonia bed loses its massive appearance and is thin but evenly bedded, gray limestone, weathering buff. These characters are retained to the northern edge of St. Joseph, with a regularly and gradually increasing thickness to the north. In the northern part of St. Joseph, however, the lens assumes its conglomeratic appearance, "ferruginous conglomerate" as Broadhead terms it, and in places attains a thickness of 16 feet.

The following section combines outcrops, shale pits, and a drilling in the vicinity of King Hill, St. Joseph:

GENERALIZED SECTION NEAR SOUTH ST. JOSEPH.

Number.	Stratum.	Thickness. Ft.	Thickness. in.
1	Loess and drift	—	—
2	Limestone, wavy-bedded; thin layers; buff shaly partings (lower part of upper limestone of Oread member)	7	
3	Covered	19	
4	Shale, drab	5	
5	Limestone, dark brown; shaly to massive (lower limestone of Oread member.)	7	
6	Sandstone and sandy shale; covered slope at bottom (top of Lawrence)	43	
7	Limestone, gray; even-bedded; weathers to buff (No. 137, Amazonia bed)	7	
8	Shale, blue, argillaceous; with brown ferruginous concretions	52	
9	Shale; very calcareous; fossiliferous; forms a resistant band where outcropping	2	6
10	Shale, red and green; argillaceous (base of Lawrence)	15	
11	Limestone, gray and compact (Iatan)	1	9
12	Shale parting (Iatan)		3
13	Limestone, gray and compact (Iatan)	2	
14	Shale, blue, argillaceous; to bottom of pit (top of Weston)	25	
15	Shale in drill hole	50	

The details of the Oread at St. Joseph are shown in the following typical section:

DETAILED SECTION OF OREAD LIMESTONE MEMBER AT ST. JOSEPH.

Number.	Stratum.	Thickness. Ft.	Thickness. in.
1	Limestone, gray, fine-grained ("Waverly flagging" in Oread member)	2	6
2	Shale, dark blue, argillaceous	3	
3	Limestone; thin and wavy-bedded; with buff shaly partings; cherty in places (upper limestone of Oread member)	21	
4	Shale, blue, argillaceous	3	
5	Shale, black, bituminous	2	
6	Limestone, gray, compact; with conchoidal fracture; generally in two layers (middle limestone of Oread member)	2	4
7	Shale, drab, clayey	9–15	
8	Limestone, buff, argillaceous (lower limestone of Oread member)	6–7	

Below this to the Amazonia limestone bed is a variable section of 34-45 feet of sandstone and shale with a thin bed of coal in places.

Broadhead assigned his number 128 to Nos. 11-13 of the St. Joseph section, supposing it to be a different limestone from number 121. It is, however, the northern thin extension of the Iatan, brought up from below the river bottom by the anticline at St. Joseph. The thicker phase of the Iatan to the south and of the Amazonia to the north also resemble each other very closely and might easily be mistaken for the same limestone, both being "limestone conglomerate." The same is true of the thin phases of the two limestones, that of the Amazonia at Rushville resembling very closely that of the Iatan at St. Joseph. The correlation of Broadhead's numbers 121 and 128 was made certain by tracing them into each other along the Platte and 102 rivers. The confusion of the two phases of the Iatan limestone caused a duplication of 96 feet in Broadhead's section, his numbers from 128 to 136 corresponding to other numbers in his section.

Holt County.—Only the upper member of the Douglas, the Oread limestone, is exposed in Holt County, and its outcrops are confined to the southeast corner. West of Nodaway River there are some large quarries in the upper limestone of the Oread, north of the Burlington Railroad tracks. Almost continuous exposures to where it dips beneath the river show the irregularities of the next limestone bed above, the so-called "Waverly flagging." In places the shale between it and the upper limestone of the Oread feathers out and in others the flagging thins to nothing. The most western outcrop of the upper limestone as formerly exposed at the river's edge near the corner of secs. 23, 24, 25 and 26, T. 59 N., R. 37 W., is now covered with debris.

Andrew and De Kalb counties.—In the eastern half of Andrew and the western half of De Kalb the Douglas is the highest formation below the drift, except possibly on the highest ridges. There are outcrops of the Iatan and Weston members in the southern part of Andrew County, on the Missouri and Platte rivers, and near Clarksdale in De Kalb County.

At the Cosby Mill on Platte River is the following section (Wheelwright):

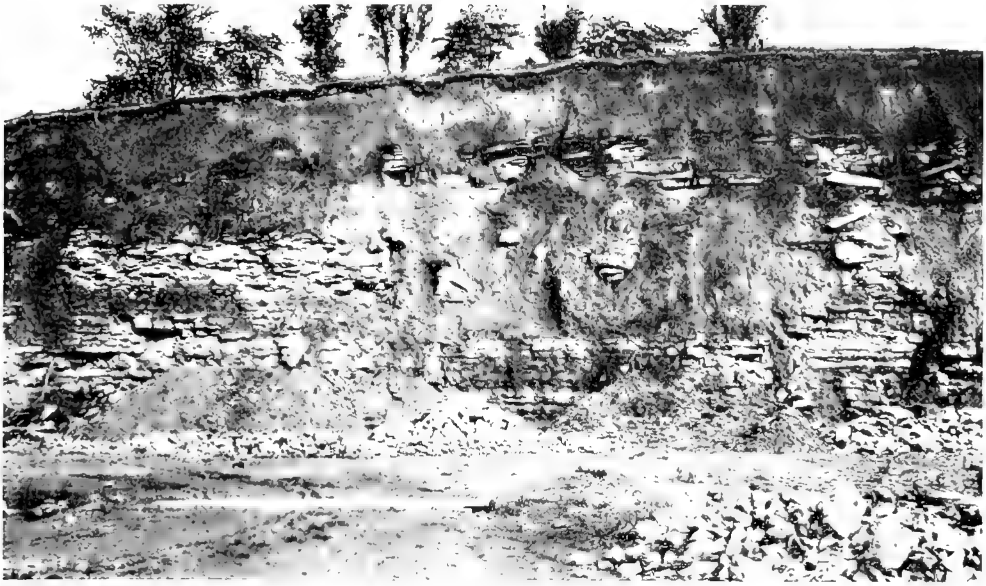


Fig. A. Oread limestone in quarry near Amazonia.

Fig. B. Amazonia limestone near Amazonia.

SECTION AT COSBY MILL.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Shale, green and red; sandy and micaceous; with an inch bed of limestone three feet above base and a thin bed of sandstone	4+	
2	Limestone, irregularly bedded; coarsely crystalline; fossiliferous; shaly partings	1	3
3	Shale, calcareous		3
4	Limestone, gray; coarsely crystalline; sugary; fossiliferous	1	8
5	Shale		½
6	Limestone like No. 4 but not so coarse at top; thin-bedded and argillaceous below		11
7	Limestone, bluish-gray, fine-grained groundmass with crystals and many fossils	1	6
8	Shale, greenish-blue; sandy; micaceous; slightly calcareous to water in river	8	

Numbers 2 to 7 are included in the Iatan limestone. On Missouri River this member passes below the bottoms two miles north of the south county line.

At Amazonia is the following section (Broadhead modified):

SECTION AT AMAZONIA.

Number.	Stratum.	Thickness.
		Feet.
1	Limestone, thin-bedded; buff wavy partings (upper limestone of Oread member)	20
2	Slope with red shale in one place	43
3	Limestone, gray; nodular at top; weathers buff (Amazonia bed)	9
4	Shale	42

This place is taken as the type locality of the Amazonia limestone bed. The bed is exposed and quarried at several places on the point east of town and in the hill west of town. It is a bed in the Lawrence shale, thinning both to the north and south, as shown by drill records on the north and outcrops on the south.

A short distance north of Amazonia is a crusher quarry belonging to Messrs. Atwood and Newell, and operating in the upper limestone of the Oread member. At the south end of the quarry the section is as follows:

SECTION AT QUARRY NORTH OF AMAZONIA.

Number.	Stratum.	Thickness. Ft.	in.
1	Limestone, gray; thin-bedded; splintery fracture; fine-grained; 30 inches to	3	3
2	Shale, dark; argillaceous; 30 inches to	3	
3	Limestone resembling above	3	
4	Limestone, blue, cherty; thin- and wavy-bedded; full of Fusulina	9	6
5	Prominent bedding plane	—	—
6	Limestone like No. 4	7	9

In places the total thickness of the upper limestone of the Oread is 22 feet.

At the north end of the quarry and in the railroad cut nearby most of the Oread is well exposed and is nearly 50 feet thick, as shown in the following:

SECTION AT QUARRY AND RAILROAD CUT NORTH OF AMAZONIA.

Number.	Stratum.		Thickness. Ft.	in.
1	Limestone, gray, oolitic; massive; weathering thin-bedded	("Waverly flagging" in Oread member)	2	
2	Shale, parting			6
3	Limestone, like above		1	
4	Shale, blue, argillaceous		3	
5	Limestone, like above	(Upper limestone of Oread member)	3	6
6	Limestone, thin- and wavy-bedded; cherty; full of Fusulina; with prominent bedding plane between this and layer below		7	
7	Limestone, like above		9	
8	Covered slope, with blue, argillaceous shale at base grading into next below		17	
9	Limestone, very shaly	(lower limestone of Oread member)		10
10	Shale			6
11	Limestone, buff		2	
12	Shale			8
13	Limestone			6
14	Shale			8
15	Limestone			8

One and one-half miles west of Amazonia, at an old quarry, Broadhead observed the following section:

SECTION ONE AND ONE-HALF MILES WEST OF AMAZONIA.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone, oolitic with splintery fracture; beds rest directly on each other without any shale parting (No. 152)	14	6
2	Shale	2	
3	Limestone, blue and brown	2	
4	Limestone, brown and blue, shelly	2	
5	Limestone, blue, shaly		3
6	Limestone, shaly		2
7	Limestone, blue and brown	1	4
8	Limestone	2	6
9	Limestone, brown	1	
10	Limestone, brown and blue; chert concretions near middle	2	6
11	Limestone, mostly brown	1	6
12	Limestone	2	

Numbers 4-12, 15 feet 3 inches thick, are the upper limestone of the Oread member. The thickness of the flagging here is rather unusual and Broadhead may have mistaken the upper part of the upper limestone for the lower part of number 152. As now exposed (the quarry having been abandoned) not over four feet of the flagging outcrops and the upper limestone is 18 feet thick, the upper three feet closely resembling the bed above it. Just west of this quarry, the Amazonia limestone bed, 7½ feet thick, dips below the Missouri flood-plain.

The following is exposed in the western part of the county where the bluff road crosses Nodaway River:

SECTION NEAR MOUTH OF NODAWAY RIVER.

Number.	Stratum.	Thickness.
		Feet.
1	Limestone, gray, thin-bedded	3
2	Shale, blue, argillaceous	2
3	Limestone; thin wavy beds with shale partings (upper limestone of Oread member)	20
4	Shale, blue or gray, argillaceous	2
5	Shale, black, bituminous, slaty	3
6	Limestone, gray, compact; in two layers (middle limestone of Oread member)	2

Practically the entire section of the Douglas is shown in the following log of the well at Savannah, Andrew County, though the driller failed to distinguish the middle limestone of the Oread:

LOG OF DRILLED WELL AT SAVANNAH, MO.

Number.	Stratum.	Thickness.	Depth.
		Feet.	*Feet.*
1	Clay, red (drift)	88	88
2	Limestone, gray	2	90
3	Clay, blue (base of Shawnee formation)	22	112
4	Limestone, gray ("Waverly flagging" in Oread member)	2	114
5	Clay shale or "soapstone"	14	128
6	Limestone (upper and middle limestones of Oread member)	24	152
7	"Soapstone"	4	156
8	Clay, red	12	168
9	Limestone (lower limestone of Oread member)	4	172
10	Clay, red, shaly (top of Lawrence)	25	197
11	Limestone (Amazonia)	13	210
12	Clay, blue	12	222
13	"Soapstone"	64	286
14	Limestone	3	289
15	Clay, blue (base of Lawrence)	13	302
16	Limestone (Iatan)	8	310
17	"Soapstone" (Weston)	60	370

Another drilling near Wyeth (NE. ¼ sec. 14, T. 60 N., R. 35 W.) shows the middle limestone of the Oread at its proper position, three feet thick.

The easternmost outcrop of the Oread seen in the counties under consideration is that south of Union Star, where only four feet of the upper Oread are exposed. The section does not differ otherwise from that on Missouri River. The lower part of the Douglas is concealed by drift along its eastern border.

Atchison and Nodaway counties.—The Douglas formation in these counties is concealed by higher formations, but drillings at Rockport[1] and Maryville reveal its presence.

Worth and Gentry counties.—It is probable that the Douglas formation is present in much of the western half of both counties, but a great thickness of drift conceals most of the indurated rocks. The best outcrops known are those along Island Branch in southwestern Gentry County, where Broadhead measured the following sections. (The correlations in parentheses are the writer's):

[1]Hinds, Henry, The coal deposits of Missouri: Bureau of Geology and Mines, vol. 11, 2nd series, p. 58, 1912.

SECTION 95.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone (lower limestone of Oread)	4	
2	Shale, yellow (top of Lawrence)		6
3	Limestone, nodular		4
4	Shale, green	1	6
5	Shale, red and green	3	

SECTION 94.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone (No. 150), (upper limestone of Oread)	17	

The coal reported between Ellenorah and Albany is thought to be in the Lawrence shale.

The Iatan limestone may be present near Gentryville (see page 168).

SHAWNEE FORMATION.

CHARACTERISTICS.

The Shawnee formation contains much more shale than limestone, but beds of limestone occur throughout the formation. The shales, when thin and associated with limestone, are argillaceous or calcareous. The thicker shales are prevailingly arenaceous and micaceous. There are several layers of black slaty shale and thin coal seams in the formation, two of the latter being fairly persistent. The thickness in the southern part of the outcrop is 475 feet, but near the Iowa-Missouri State line decreases to 350 feet.

The Shawnee formation transgresses a faunal boundary, the Howard limestone, 200 feet below the top, marking, according to Beede and Rogers,[1] the extinction of 28 species of Pennsylvanian invertebrates, a fact which may call for a revision of the boundary at some future time. The outcrop is shown on the State geologic map.

[1]Beede, J. W., and Rogers, A. F., Coal measures faunal studies: Kansas Univ. Geol. Survey, vol. 9, pp. 345-346, 1908.

MEMBERS.

Kanwaka shale member.—The basal member of the Shawnee is a shale and sandstone bed, 30 to 50 feet thick, containing locally two thin streaks of coal.

Lecompton limestone member.—The Lecompton is an assemblage of thin alternating limestones and shales varying from 20 to 30 feet in thickness. Most of the layers weather to a deep buff and some of them have a cellular appearance. In drillings limestones at this horizon are often reported as "chalk rock." Near the middle of the member is a layer of black shale. The chief characteristic of the Lecompton is the number of large spines and plates of Echinoidea from which the name "sea-urchin" limestone arises.

Tecumseh shale member.—The Tecumseh is commonly a shale member but contains some sandstone in places. Along Missouri River it is 60 feet thick, but thins to the north as shown in drillings and in Todd's Missouri River section,[1] where this and the two preceding members are assigned a thickness of only 69 feet.

Deer Creek limestone member.—The Deer Creek consists of three limestones with intervening shales. The lower limestone is a soft, buff, argillaceous layer about five feet thick; the lower shale is seven feet thick; the middle limestone is a gray, fine-grained limestone, containing specks of calcite, divided into two layers, the lower 16 to 20 inches and the upper 4 inches thick; the upper shale is five feet thick, black and slaty in the middle; the upper limestone is gray, cherty, thick- or thin-bedded, oölitic in the upper part and weathering buff on the bedding planes. This upper limestone is 13 to 15 feet thick in Missouri.

Calhoun shale member.—The lower part of the Calhoun is argillaceous and contains one or two thin layers of limestone at the bottom. Next above the shaly portion along Missouri River is a six-inch layer of blue limestone, a few inches of shale, and then another blue limestone one or two feet thick. Above the limestone lentils the Calhoun is prevailingly sandy shale or sandstone with a streak of coal in places. The thickness of the whole is 20 to 25 feet.

Topeka limestone member.—The Topeka limestone is composed of 25 feet of blue and buff limestone with interbedded shale,

[1] Todd, J. E., Some variant conclusions in Iowa geology: Iowa Acad. Sci. Trans., vol. 13, pp. 183-186, 1906.

the whole of which, with the exception of a persistent layer of black slaty shale, weathers to a deep buff. The individual beds of limestone and shale appear to be rather persistent, though varying in thickness in short distances and thereby making correlations difficult in some cases. The uppermost beds of the Topeka do not outcrop on the Missouri River, but appear in Nodaway County.

Severy shale member.—The lower part of the Severy is arenaceous and the upper part commonly bituminous, containing over a wide area the Nodaway or Quitman coal (Osage or Topeka coal of Kansas). The Nodaway coal is from two to thirty inches thick and is overlain by black slaty shale. At Forest City the Severy is 30 feet thick but decreases to the north. More coal mining has been done in it than in any other member of the Missouri group in Missouri.

Howard limestone member.—The cap-rock of the Nodaway coal is the Howard limestone. It consists of two limestones remarkable for their persistency, as they are each less than two feet thick. The lower limestone is blue and the upper is gray. The intervening shale is two to eight feet thick and is argillaceous or calcareous. The Howard is often reported as solid limestone in drillings.

Scranton shale member.—At the top of the Shawnee formation is a shale member about 200 feet thick, the Scranton shale. The lower half is prevailingly clay and sandy shale or sandstone; the upper half contains a number of thin, buff-weathering limestones. Near the middle of the Scranton is a coal horizon, containing locally the Elmo coal (Silver Lake coal of Kansas). The shale near the top of the Scranton is commonly variegated. On account of its soft nature the Scranton was eroded deeply prior to the deposition of the Kansan drift and good outcrops are rare. No complete outcrop has been found in the State. Farther south, in Kansas, it appears in the faces of escarpments capped by the overlying Burlingame limestone (probably same as Tarkio limestone of this report).

REGIONAL VARIATION AND DETAILED SECTIONS.

For convenience the detailed description of Shawnee formation is combined with that of the Wabaunsee formation.

WABAUNSEE FORMATION.

CHARACTERISTICS.

At the top of the Pennsylvanian series in Missouri there are about 100 feet of strata lying at the base of the Wabaunsee formation, which in Kansas and Nebraska contains more members and is much thicker than in Missouri. The bulk of the formation is sandy shale and sandstone, but there are three or more persistent layers of limestone and one irregular coal seam, the Nyman. The outcrop is confined to Atchison and northwestern Holt counties.

SUBDIVISIONS.

Tarkio limestone member.—The Tarkio is a thin member consisting of a basal bed of limestone about four feet thick, above which are one or two thin layers of limestone separated by shale. The limestones are blue but weather to a deep buff color. The shales are red and blue and contain more or less nodular limestone. The thickness of the whole is 10 to 14 feet. In the southern part of Atchison County a small escarpment is capped by the Tarkio limestone.

Undifferentiated beds.—Above the Tarkio are about 20 feet of shale and sandstone overlain by the Nyman coal seam, a bed only a few inches thick. The Nyman coal has a cap-rock about two feet thick, consisting of one or two layers of limestone that is nodular at the top. This may be the equivalent of the Emporia limestone. The remainder of the formation as found in Missouri is about 50 feet thick and composed largely of sandy shale and sandstones, but containing one or two thin layers of sandy limestone. There is a possibility that one of the latter, instead of the Nyman cap-rock, may be the Emporia limestone of Kansas geologists.

REGIONAL VARIATION AND DETAILED SECTIONS.

Buchanan County.—The lower part of the Shawnee formation outcrops in the southern part of the county, south of the St. Joseph anticline. The best outcrops occur on Contrary Creek. The section at Atchison, Kans. (see page 176) is much better than any exposed in Buchanan County and is, therefore, substituted. Nos. 2-10 of that section comprise the Lecompton limestone and Nos. 11-17 the Kanwaka shale. The section corresponds closely to that of Broadhead.

Holt and Andrew counties.—In the greater part of Holt and the western half of Andrew County the Shawnee is the highest indurated formation. In the northwestern corner of the former is the Tarkio member of the Wabaunsee.

The drift is very deep in these counties, so that outcrops are confined to the bluffs of the Missouri and Nodaway rivers and their larger tributaries. The Scranton shale seems to have been subjected to a large amount of preglacial erosion. From the mouth of Kimsey Creek to the vicinity of Corning there are no outcrops of the Missouri group along the Missouri River, and, consequently, Broadhead was unable to connect the Atchison County section with that of Holt County, supposing a gap of fifty feet to intervene. It has since been learned that this gap amounts to only fifteen feet. This will be more fully discussed in the description of Nodaway County.

The following generalized section near the mouth of Nodaway River shows the lower part of the Shawnee formation:

GENERALIZED SECTION NEAR MOUTH OF NODAWAY RIVER.

Number.	Stratum.	Thickness. Ft.	in.
1	Limestone, gray and buff (upper limestone of Deer Creek member)	15-20	
2	Shale, blue, argillaceous, and black, bituminous	5	
3	Limestone, gray, compact; full of calcite streaks; weathers buff (in two layers—upper 4 inches, lower 1 foot 8 inches); (middle limestone of Deer Creek member)	2	
4	Shale, drab	11	
5	Limestone, buff; two layers with shale partings (lower limestone of Deer Creek member)	4	
6	Shale, blue; argillaceous and arenaceous; micaceous (top of Tecumseh)	52	
7	Limestone "conglomerate" corrugated; resembles the Iatan and Amazonia	2	
8	Shale, blue and buff (base of Tecumseh)	8	10
9	Limestone, gray; buff shaly partings; thin- and wavy-bedded (top of Lecompton)	5	6
10	Shale, blue, argillaceous	2	
11	Shale, black, bituminous	2	
12	Shale, argillaceous		4
13	Limestone, dark; full of Fusulina	1	
14	Shale, buff; calcareous at top ("chalk"); argillaceous at bottom	9	8
15	Shale, buff and white; calcareous	4	
16	Limestone, buff; in three layers with shale partings; contains many spines of Echinocrinus (base of Lecompton)	5	6
17	Shale, gray or blue; argillaceous or arenaceous; in places, sandstone (top of Kanwaka)	25	
18	Limestone, gray; even-bedded; in two layers	2	6
19	Shale, drab, argillaceous (base of Kanwaka)	16–20	
20	Limestone (top of Douglas formation)	—	—

The close resemblance of the lower part of this section to Kneer's Atchison section is clearly apparent.

The thickness of the section between the upper limestone of the Oread member and the upper limestone of the Deer Creek member was found to be 172 feet near the town of Nodaway. Broadhead gives 180 feet for this interval, but interpolated between numbers 5 and 6 of the foregoing section his numbers 171-181 aggregating 42½ feet, 37½ feet of which he found outcropping on Brockman Branch in Holt County. This is probably a repetition of the Lecompton section. The beds below his number 169 are in places given a thickness rather under the normal, which accounts for his total thickness being almost correct.

The Calhoun shale and Topeka limestone are exposed one mile west of Fillmore, and are thought to be the highest rocks in Andrew County.

At Forbes the base of the Lecompton limestone is slightly above the railroad grade and a short distance above the town it dips below the bottoms. About two miles above Forbes (NE. ¼ sec. 23, T. 59 N., R. 38 W.) the Howard limestone appears in the bluff, but the section below is poorly exposed.

The following section was measured in the quarry at Forest City:

SECTION AT FOREST CITY.

Number	Stratum.	Thickness. Ft.	in.
1	Shale, buff; with 3 or 4 nodular layers of limestone (top of Topeka)	3	
2	Limestone, gray; irregularly bedded; in two layers		10
3	Shale, blue, and black, bituminous	2	3
4	Limestone, gray; wavy base	1	2
5	Clay, blue; non-laminated; indurated	1	5
6	Limestone, gray		9
7	Shale, blue and blue-black; argillaceous	2	1
8	Limestone; 2 or 3 lenticular layers with interbedded shale	1	4
9	Shale, blue, argillaceous	1	7
10	Limestone, blue; weathers salmon-colored	1	2
11	Shale, blue; weathers buff; calcareous nodules	2	6
12	Limestone, buff (base of Topeka); 16 inches to	1	9
13	Shale, brown calcareous (top of Calhoun)	2	6
14	Limestone		4–6
15	Shale, sandy		7
16	Sandstone	1	6
17	Sandstone	3	
18	Shale, sandy		9
19	Sandstone	2	3
20	Shale, blue, argillaceous	1	4
21	Limestone, sandy	1	2
22	Shale, brown		2

SECTION AT FOREST CITY—Continued.

Number.	Stratum.	Thickness. Ft.	Thickness. in.
23	Shale, black, bituminous		1
24	Limestone, grayish-blue	1	
25	Shale, grayish-blue		1
26	Limestone, grayish-blue		6
27	Shale		3
28	Limestone, grayish-blue	2	3
29	Covered to water in creek	10	

The concealed interval is about the noımal thickness to the top of the Deer Creek limestone as shown in Broadhead's Forest City section (revised and corrected by the writer):

BROADHEAD'S SECTION NEAR FOREST CITY.

Stratum.	Broad-head's numbers	Thickness. Ft.	Thickness. in.
Limestone, brown, shaly; at base is a 4-inch grayish-blue layer of carbonate of lime and iron (top of Howard)	220	1	
Shale	219	4	
Limestone, ash-blue; silicious and pyritiferous (base of Howard)	218	1	6
Sandstone (top of Severy)	217		10–16
Shale, bituminous; absent in places, maximum	216	2	6
Clay, sandy	——		2
Coal (Nodaway)	215		4
Shale, light blue, clayey	214	2	
Shale, sandy	214		2
Shaly slope; shale at bottom	——	25	
Limestone; shaly and nodular (top of Topeka)	210		3
Shale, with brown, concretionary nodules of limestone	210	1	6
Limestone, rough, concretionary	210		10
Shale	210		10
Limestone, blue, even-bedded	209		10
Shale, blue	207	2	
Limestone, blue	206	1	1
Shale	205	10	
Limestone, ash-blue, weathers brown	199	1	6
Shale, yellow, gray streaks	——	2	10
Limestone, brown (base of Topeka)	197	1	6
Shale, yellow; bands of bituminous shale in the lower part (top of Calhoun)	196	7	
Sandstone	193	2	6
Limestone, grayish-blue	192	1	6
Shale	191		5
Limestone, gray; abounds in many fine univalves	190		6½
Shale, blue	189	3	6
Limestone, deep-blue, even layer	——		4
Shale, blue; at the base of this and resting on No. 186 is a calcareous stratum (base of Calhoun)	——	8	
Limestone (Deer Creek)	186	—	—

Broadhead's number 217, which he called a sandstone, is a slightly arenaceous limestone about 80 per cent of which is composed of Ostracod shells.

The upper limit of the Topeka limestone is well defined at Forest City, being the top of Broadhead's number 210, but there is some question as to its lower limit. Tentatively, this is drawn at the base of Broadhead's number 197, including a total thickness of about 20 feet. The Topeka limestone may include, however, his numbers, 190-1-2. If Broadhead's number 197 is considered the base of the Topeka limestone, the Calhoun shale is about 26 feet thick. His numbers 211 and 212 are lenticular and are not represented at Forest City.

The following is a section at Iowa Point, Kans. (Broadhead):

BROADHEAD'S SECTION AT IOWA POINT, KANS.

Number.	Stratum.	Broadhead's numbers.	Thickness. Ft.	Thickness. in.
1	Shale, brown, calcareous; contains many fossils	—	1	6
2	Limestone, brown; with Fusulina	210	1	
3	Shale, brown	—		8
4	Limestone, concretionary	209		10
5	Shale, blue; bituminous	207	2	6
6	Limestone, blue	206	1	
7	Shale, blue	201-203	4	
8	Limestone, gray	199	1	2
9	Shale, blue above, brown below	198	4	
10	Limestone, blue, nodular, shaly	197		6
11	Shale, brown, calcareous	196	2	
12	Limestone, blue, nodular, shaly	—		6
13	Shale, olive and blue; a few thin coal laminae	193-195	8	
14	Limestone, bluish-gray, nodular	192	1	6
15	Shale, brown	192		2
16	Limestone, bluish-gray; weathers brown	192	3	6
17	Shale, olive	191		9
18	Limestone, bluish-gray	190		6
19	Shale, blue	—	2	
20	Slope, shaly	—	7	
21	Limestone	186	6	

Number 21 is the Deer Creek limestone; Nos. 11-20, the Calhoun shale; and Nos. 1-10, the Topeka limestone.

Atchison and Nodaway counties.—Owing to the heavy covering of glacial drift, outcrops are rare in these counties and are confined to the bluffs of the larger streams. All outcrops of hard rock belong to the Shawnee and Wabaunsee formations.

Atchison County has the distinction of having the highest, or youngest Pennsylvanian strata in the State. The lowest member known to outcrop is the Tecumseh shale.

The following section taken in the SE. ¼ SE. ¼ sec. 4, T. 64 N., R. 33 W., is referred to the Tecumseh shale:

SECTION NORTH OF RAVENWOOD.

Number.	Stratum.	Thickness.
		Ft. in.
1	Shale, drab; red at top; argillaceous	10+
2	Coal, poor	1–4
3	Shale; drab; clayey and sandy; with layers of hard calcareous sandstone; bedding very irregular	8+

The Deer Creek limestone is exposed along 102 River, especially north of Barnard and at intervals along Platte River. The following section was taken near Ravenwood in the SW. ¼ SW. ¼ sec. 6, T. 64 N., R. 33 W.:

SECTION NEAR RAVENWOOD.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone, gray; weathers buff; thick to thin beds; wavy-bedded and cherty in lower part, more even and non-cherty above; weathers to fragments size of hand	5	
2	Shale, drab, argillaceous; with streak of black shale near base		10
3	Limestone, gray, thin-bedded; somewhat argillaceous; with small chert nodules	6	

Across the wagon road to the east, No. 1 of the previous section is much better exposed. A detailed measurement is as follows:

UPPER PART OF DEER CREEK LIMESTONE MEMBER NEAR RAVENWOOD.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone, gray; even-bedded; non-cherty		6
2	Limestone		5
3	Limestone		8
4	Limestone, shelly		4
5	Limestone, like No. 1		4
6	Limestone, in 2 layers		11
7	Shale		2
8	Limestone, gray, wavy-bedded, cherty	1	2
9	Limestone, like No. 8	1	2
		5	8

The limestone lentils in the Calhoun shale (numbers 190-192) were not seen in Nodaway County, but may be represented in the following section taken on Dog Creek, one-half mile above its mouth (Broadhead):

BROADHEAD'S SECTION HALF-MILE ABOVE MOUTH OF DOG CREEK.

Number	Stratum.	Thickness. Ft.	in.
1	Slope	—	—
2	Loose fossils overlying next below	—	—
3	Limestone, blue; weathers brown	1	4
4	Slope	7	
5	Shale, brown (base of Calhoun)	2	
6	Limestone, irregularly bedded (Deer Creek)	7	

The following section was taken by Broadhead on Dog Creek, in the NW. 1/4 NW. 1/4, sec. 26, T. 62 N., R. 33 W.:

BROADHEAD'S SECTION ON DOG CREEK.

Number	Stratum.	Broadhead's numbers.	Thickness. Ft.	in.
1	Slope	—	—	—
2	Shale, olive	210	1	
3	Limestone, ash-blue	209		5
4	Shale, upper half a dark olive and calcareous, bituminous below	207	1	11
5	Limestone, blue; interior of the fossils is crystallized calcite	—		10
6	Shale, olive and blue; somewhat sandy	—	4	
7	Shale and nodular limestone	—	2	
8	Limestone, gray, coarse, sub-oolitic	201		7
9	Shale, nodular, calcareous	200		6
10	Limestone, ash-colored, coarse, shaly	199	2	6
11	Shale, olive	—	1	1
12	Limestone, dull, deep ash-blue; weathers drab	—	3	
13	Shale; dark-blue, calcareous	196		7
14	Limestone, bluish-gray, uneven bed; contains calcite veins and specks, and zinc blende	—		9
15	Shale, dark, sandy, micaceous	—		9
16	Coal	—		1½ to 2″
17	Sandstone, black; even layers; regularly laminated; slightly calcareous	—		5
18	Clay, sandy	193		8
19	Fire clay, blue; 3 feet exposed; said to be 6 or 7 feet thick	—	3	

Number 14 of this section and all above are to be included in the Topeka limestone; below that, in the Calhoun shale.

The following section, modified from that of the Broadhead, includes a detailed description of the Topeka limestone; the section was measured near the present site of Skidmore (sec. 5, T. 63 N., R. 37 W.):

BROADHEAD'S SECTION NEAR SKIDMORE.

Number.	Stratum.	Broadhead's numbers.	Thickness. Ft.	in.
1	Limestone, deep-blue; compact; in even 6- to 10-inch layers	212	2	
2	Limestone, deep ash-blue	211		6
3	Shale, buff, and fossiliferous limestone nodules	210	4	
4	Limestone, blue; abundantly fossiliferous; brachiopods are generally replaced by calcite	209		10
5	Shale, blue, calcareous; fossiliferous	——	1	
6	Shale, black, slaty	——		1
7	Shale, dark blue	——		9
8	Shale, black, slaty	——		5
9	Shale, olive	——		3
10	Limestone, deep-blue; contains many fossils; interior of fossils replaced by calcite	——		10
11	Shale, brown, ochery	——		2
12	Shale, gray	——	1	6
13	Shale, green, nodular	——	2	
14	Shale, yellow; has nodular limestone layers	——	2	4
15	Limestone, buff; suboolitic	——	1	
16	Limestone, dull ash-blue, has shaly partings	199	3	
17	Shale, dark olive	——		9
18	Limestone, dark-ash	197	1	

All the above are included in the Topeka limestone.

Broadhead's numbers 211 and 212 are irregular and not represented at Forest City, but occur in Nodaway County. The following section (NW. ¼ NE. ¼ sec. 35, T. 64 N., R. 37 W. on Florida Creek) shows these beds:

SECTION ON FLORIDA CREEK, SOUTHWEST OF MARYVILLE.

Number.	Stratum.	Thickness. Ft.	in.
1	Limestone (lower bed of Howard)	1	3
2	Covered (top of Severy)	5	
3	Alternating layers of micaceous sandstone and micaceous sandy shale	22	
4	Limestone, gray, compact; layers extremely regular, and shale, blue, argillaceous (Nos. 211-12), (top of Topeka) as follows	4	2

SECTION ON FLORIDA CREEK, SOUTHWEST OF MARYVILLE—Cont'd

Number.	Stratum.		Thickness.
		Ft. in.	
	Limestone, two layers	7	
	Shale	1	
	Limestone	4	
	Shale	1	
	Limestone	3	
	Shale	1	
	Limestone	2½	
	Shale	2¾	
	Limestone	5½	
	Shale	4	
	Limestone	2½	
	Shale	4	
	Limestone in three layers below water in creek	1	

The Howard limestone forms the cap rock of the Nodaway or Quitman coal. This coal has been found outcropping along the Nodaway River from Graham to a point north of Quitman. Here it dips below drainage, but has been reached by shafting in several places as far north as Burlington Junction. Near the Iowa line it again appears above the river. It has been found on White Cloud, Florida and Sand creeks, south of Arkoe, and west of Hopkins on the west side of 102 River. In the immediate vicinity of Maryville it seems to have been removed by preglacial erosion, as the deep drilling at that place failed to find it.

The following section is modified from that taken at Quitman by Broadhead:

SECTION AT QUITMAN.

Number.	Stratum.	Thickness. Ft.	in.
1	Slope of bluff clays	—	—
2	Limestone, blue, spathic (upper limestone of Howard member)	1	10
3	Shale, sandy	2	6
4	Limestone, ash-blue (lower limestone of Howard member)	2	
5	Shale, olive and drab; lower half fossiliferous (top of Severy)	2	2
6	Coal (Nodaway)	1	2
7	Clay, gray and ochery, sandy; with remains of plants	2	6
8	Shale, sandy	8	5
9	Sandstone, brownish-drab; irregularly bedded	4	
10	Shale, sandy	7	
11	Shale, blue, argillaceous (No. 213)	1	
12	Slope, shaly	3	
13	Shale, dark blue	2	
14	Limestones, blue, compact (top of Topeka)	2	

Howard limestone overlying Severy shale, Quitman.

Above the Howard limestone is a terrane which has probably been the subject of more discussion than any other part of the Missouri group, including as it does the Nebraska City section. As shown in the next section, the lower part of the Scranton shale, which is next above the Howard limestone, consists of about one hundred feet of poorly consolidated shale which preglacial erosion has largely removed from the region along Missouri River.

BROADHEAD'S GENERALIZED SECTION ABOVE THE HOWARD LIMESTONE MEMBER.

Stratum.	Broad-head's numbers.	Thickness.	
		Ft.	*in.*
Limestone, shelly, porous, ferruginous	224	4	
Shale; septaria occur near upper part	223	36	
Septaria	222	1	6
Shale	221	48	

In his Nodaway County report he says there are 100 feet of shale between number 224 and the Nodaway coal. Number 224, "closely resembling the buff limestone over the coal at Rulo and the mouth of the Big Nemaha in Nebraska" caps what Broadhead thought to be the highest rocks in Nodaway County. Between this and the base of his Atchison County section he estimated a thickness of 40 or 50 feet to intervene.

The section at Elmo, Nodaway County, near the center of sec. 28, T. 66 N., R. 37 W., measured as follows:

SECTION NEAR ELMO.

Number.	Stratum.	Thickness.
		Feet.
1	Shale, gray, sandy	2
2	Limestone, gray; shaly at top; loose nodules at bottom	1
3	Shale, gray	1
4	Coal, bituminous (Elmo)	1
5	Shale, with thin layer of clay at top	13
6	Limestone, salmon-colored; argillaceous, nodular at bottom	2

Number 1 is the lower part of No. 27 of the Atchison County section; No. 2 is No. 28 of the Atchison County section; and No. 6 is number 224 of the Missouri River section.

The Elmo coal also outcrops northwest of Burlington Junction (City Bluffs of Broadhead) with its characteristic irregular cap rock. It is probably the equivalent of the Silver Lake coal of Kansas which is about 120 feet above the Osage or Topeka coal. In Kansas it has an irregular cap rock as in Missouri. For the present it will be called the Elmo coal.

SECTION NEAR MILTON.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Limestone fragments; not in place	—	—
2	Shale	20	
3	Limestone, gray, very shaly (No. 28 of Atchison County section)	1	
4	Covered, yellow, ochery, sand at top	2	
5	Limestone, brown		6
6	Shale, yellow, ocherous, sandy (horizon of Elmo coal)	—	—

Along Missouri River the lowest member of Broadhead's Atchison County section is exposed near where the line between secs. 34 and 35, T. 63 N., R. 40 W., crosses the bluffs. At that place shaly limestone, No. 28, outcrops, underlain by a foot of light shale and that in turn by black shale and coal, according to Mr. Fisher on whose farm this outcrop is located.

Concerning the stratigraphy along Missouri River above this point there is little to be added to Broadhead's Atchison County section, given in the generalized section of the Missouri group and here repeated for convenience in Broadhead's wording, the correlations in parentheses being the writer's.

ATCHISON COUNTY SECTION.

No. 1.—250 feet bluff.
2.—Drift; thickness unknown, beneath the bluff.
3.—5 feet red shales.
4.—Sandstone and shales; sandstone at top, upper three feet irregularly-bedded and micaceous, green; below, 8 or 10 feet soft brown; then 35 feet shales and sandstone at bottom.
5.—10 inches drab limestone; weathers brown.
6.—3 feet 2 inches shaly limestone, containing fossils.
7.—1 foot 4 inches blue, concretionary limestone, traversed by calc-spar veins.
8.—2 inches sandy shale or dark brown clay.
9.—2 inches impure coal and shale, two to three inches.
10.—Ochery, sandy shale.
11.—22 feet sandy shale.
12.—1 foot 6 inches dark blue, shaly limestone (top of Tarkio).
13.—1 foot 6 inches red and green shale; with nodules of limestone.

14.—4 feet limestone, upper part nodular; weathers brown; abounds in Fusulina.
15.—28 feet blue and drab, argillaceous shale (top of Scranton).
16.—2 feet limestone, bluish-drab.
17.—10 inches blue, fossiliferous shale.
18.—2 feet 6 inches hard sandstone.
19.—3 feet soft sandstone.
20.—10 inches calcareous sandstone; springs abound at the base.
21.—6 feet blue, argillaceous shale, 6 feet to 13 feet.
22.—1 foot tolerably fine-grained, blue limestone, perpendicularly jointed; weathers brown.
23.—1 foot 3 inches shale.
24.—10 inches buff, ochery, decomposing limestone; jointed perpendicularly.
25.—2 feet buff and olive shale.
26.—2 feet red shale.
27.—30 feet clay and sandy shale, and concretionary layers of sandy ironstone.
28.—Shelly limestone.

Near Corning (center sec. 18, T. 63 N., R. 40 W.) a well is said to have penetrated coal at a depth of 80 feet and another bed (probably the Nodaway) at 180 feet. From nearby outcrops it is estimated that the Scranton shale is here about 195 feet thick. The following section was taken in the NE. ¼ sec. 22, T. 64 N., R. 41 W. on the farm of Mr. John Whitham:

SECTION SOUTHEAST OF LANGDON.

Number.	Stratum.		Broadhead's numbers.	Thickness. Ft.	Thickness. in.
1	Limestone		5	1	6
2	Shale, black		—		9
3	Limestone		7		17–19
4	Shale		8		6
5	Coal (Nyman)		9		8
6	Clay		—		2
7	Covered		11	18	
8	Limestone, dark blue	(Tarkio)	12	1	6
9	Clay, red, non-laminated	(Tarkio)	13	1	6
10	Limestone, brown, massive	(Tarkio)	14	3	6
11	Shale, blue (top of Scranton)		15	4	8
12	Slope covered with shale at bottom		15	22	

The shale bed at the base of this section (Broadhead's number 15) decreases to 12 feet near the State line, but that between the Tarkio limestone and the Nyman coal increases about 10 feet in the same distance.

The Tarkio limestone dips under the bottoms near the south line of sec. 20, T. 65 N., R. 41 W. The following section outcrops at this place:

SECTION WEST OF ROCKPORT ON BLUFF OF MISSOURI RIVER.

Number.	Stratum.	Broad-head's numbers.	Thickness.
			Ft. in.
1	Calcareous sandstone	—	1+
2	Sandstone, shaly sandstone, and very micaceous shale; in places black with biotite	4	30±
3	Limestone, impure, fossiliferous	5, 6, 7	2
4	Shale, carbonaceous in places (Nyman coal horizon)	8, 9	2–6
5	Shale, sandy, micaceous	11	25
6	Limestone, very concretionary and impure (Tarkio)	—	8–12
7	Shale with calcareous concretions (Tarkio)	13	3 6
8	Limestone, brown, with Fusulina (Tarkio)	14	2+

Above the cap rock of the Nyman coal there appears to be little regularity in the section, which consists chiefly of sandstone and shale. There are, however, one or two thin layers of calcareous sandstone or sandy limestone that seem to be fairly persistent 15 to 30 feet above the Nyman cap rock. One of these lies at the top of the section west of Rockport and one or both of them appear in the sections measured by Broadhead at Hall's Bridge, a few miles south of the State line, and at the State line.

BROADHEAD'S SECTION AT HALL'S BRIDGE (MODIFIED).

Number.	Stratum.	Thickness.
		Feet.
1	Limestone, hard, sandy and ferruginous; fracture shows a dull lead-blue color; weathers brownish	1
2	Sandstone, greenish-drab, fine-grained; slightly micaceous; irregularly bedded	3
3	Limestone, brown and greenish, very coarse-grained and tough; sandy and micaceous	1
4	Sandstone, brown and buff; soft	4
5	Shale; upper half sandy; lower half argillaceous	16
6	Shale; with nodules of brown and ferruginous limestone (Nyman cap-rock)	2

BROADHEAD'S SECTION NEAR THE STATE LINE (MODIFIED)

Number.	Stratum.	Broad-head's numbers.	Thickness.
			Ft. in.
1	Shale; blue-banded; ochery, argillaceous, clay shale thinly laminated	—	2
2	Limestone, dark gray; weathers brown	5	10

BROADHEAD'S SECTION NEAR THE STATE LINE (MODIFIED)—Continued.

Number.	Stratum.	Broadhead's numbers.	Thickness.	
			Ft.	*in.*
3	Limestone; rather shaly; fossiliferous	7	2	
4	Clay, dark brown	8		2
5	Ochre, dark, and coal, interbedded	9		3
6	Shale, ochery, sandy	—		2
7	Shale, variegated, ochery, and blue, sandy	—		17

Two miles northwest of Hamburg, Iowa, and about the same distance north of the State line, at McKissicks Grove, is the type section of the McKissicks Grove shale of Smith.[1] His section, slightly modified, is as follows:

SECTION AT McKISSICKS GROVE, IOWA.

Number.	Stratum.	Broadhead's numbers.	Thickness.	
			Ft.	*in.*
1	Shale, gray	—	7	
2	Limestone, weathered	—	1	
3	Limestone, very dark; containing nodules about ½ inch in diameter	—	1	
4	Shale, blue, sandy and micaceous; with several thin bands of sandstone	—	7	
5	Sandstone, blue, weathering to yellow; micaceous	—	3	
6	Shale, gray, sandy	—	15	
7	Limestone, gray, compact	7	1	
8	Limestone, impure	9	1	
9	Coal (Nyman)	—		9
10	Shale, sandy, and sandstone	10–13	20	
11	Limestone			6
12	Shale, dark		3	6
13	Limestone			6
14	Shale, blue, weathering to yellow		8	
15	Limestone; in two or three heavy ledges crowded with Fusulina	14	4	
16	Shale	15	12	
17	Limestone, dark gray	16	1	

No. 15 of this section is the main ledge of the Tarkio limestone, and the shale and limestone below are referred to the Scranton shale as interpreted in this report.

[1]Smith, G. L., The Carboniferous section of southwestern Iowa: Iowa Geol. Survey, vol. 19, pp. 605-658, 1909.

At Nebraska City, Nebr., are outcrops whose age was formerly considered doubtful, but has in later years been shown conclusively to be Pennsylvanian. Smith[1] gives the following section at the shale pit:

SECTION AT SHALE PIT AT NEBRASKA CITY, NEBR.

Number.	Stratum.	Thickness.	
		Ft.	*in.*
1	Thin-bedded limestone, impure with shaly partings; some crinoid stems	4	
2	Yellow, very arenaceous shale	4	
3	Blue shale	5	
4	Heavy layer limestone	2	
5	Thin seam, very carbonaceous matter, with plant impressions		3
6	Blue, laminated and non-laminated shale, micaceous and arenaceous in places. In part of the exposure divided by a thin band of more indurated shale, yellowish in color. Ten feet above the base of the shale is a thin band of limestone	40	
7	Limestone	2	
8	Shale	6	
9	Crinoidal limestone	1	
10	Shale	1	
11	Limestone in two layers	1	
12	Shale, exposed in bed of small intermittent creek	—	—
		66	3

Smith correlates No. 5 of the above with the Nyman coal. The writer visited this exposure in company with Dr. Smith and is inclined to believe this correlation correct. In this case, Nos. 7 to 12 are the upper layers of the Tarkio limestone, and the main ledge is probably just below water level.

The following partial log of a drilling at Nebraska City confirms the above correlation:

LOG OF DRILLING AT NEBRASKA CITY, NEBR.

Stratum.	Thickness.	Depth.
	Feet.	*Feet.*
Soil	4	4
Lime (Tarkio)	4	8
Shale (top of Scranton)	25	33
Lime	2	35
Shale, red	5	40
Shale, blue	15	55
Shale, red	5	60
Shale, blue	22	82

[1]Op. cit.

LOG OF DRILLING AT NEBRASKA CITY, NEBR.—Continued.

Stratum.	Thickness.	Depth.
	Feet.	*Feet.*
Limestone (Elmo cap rock?)	5	87
Shale, blue	32	119
Shale, red	6	125
Sandstone	2	127
Shale, blue (base of Scranton)	73	200
Lime (Howard)	9	209
Shale, black (horizon of Nodaway coal)	6	215

Another drilling, one mile below the shale pit shows:

CONDENSED LOG OF CROXTON BORING NEAR NEBRASKA CITY, NEBR.

Stratum.	Thickness.	Depth.
	Feet.	*Feet.*
Alluvium	17	17
Shale, sandstone and six thin layers of limestone (base of Scranton)	176	193
Limestone, blue (Howard)	5	198
Coal (Nodaway)	1 ¼	199 ¼

CHAPTER V.

STRUCTURE.

REPRESENTATION OF STRUCTURE.

Delineation.—Regional structure may be shown in three ways, by cross-sections, by models, and by structure contours. Cross-sections on a small scale, such as those in Chapter I, serve a useful purpose in showing graphically the general strike and dip of the rocks, but in a region where the rocks are so nearly horizontal as in Missouri, both cross-sections and models are inadequate. In this region structure contours delineate the structure in greater detail.

Structure contours.—A structure map is constructed by plotting the altitude of a given datum plane (some easily recognized stratum, such as a coal bed) at all points where it can be determined. Points are then united by lines known as structure contours, along each of which the datum plane is supposed to have the same altitude. Between any two structure contours the stratum selected as the datum plane has an altitude intermediate between those of the structure contours on each side. The structure contours generally have no connection with contour lines showing the surface topography, and the folds usually are not clearly related to surface features. When the structure contours have been placed on the map they show the regional dip and strike, the direction and magnitude of the folds, and the altitude of the datum plane. Where the surface altitude is known, the depth of the datum plane may be readily computed.

Data for structure contours.—The method described in the previous paragraph was used in constructing the structure map of the Missouri Pennsylvanian (Plate XXIII), the Bevier coal being selected as the datum plane on account of its great persistency. Although structure contours have been drawn on this horizon over most of the Pennsylvanian area of the State, the writer does not mean to imply the existence of the Bevier coal under the entire area. East of Range 25 and north of Missouri River, there are many outcrops of the Bevier bed; also many mine shafts and drill holes that furnish data on its altitude. In this district, therefore, the altitudes have been taken directly from the Bevier

STRUCTURE MAP.

coal. In the district south of Missouri River, the Bevier coal cannot be certainly identified, and an arbitrary horizon 100 feet below the upper limestone of the Fort Scott member has been used as a datum plane. In the remainder of the Pennsylvanian area elevations were first plotted on the base of the Hertha limestone and were lowered 300 feet, that being about the average vertical distance between the Hertha limestone and the Bevier coal horizon.

Accuracy of structure contours.—The preliminary nature of the map has been noted. The reasons for this are many. Only a small proportion of the coal-bearing portion of the State is covered by accurate topographic maps, so that the majority of the altitudes, whether on outcrops, shafts, or drill holes, had to be obtained by barometer or, in a few cases, by guess. In the northwestern counties only a few drill records reach the Hertha limestone and even a smaller number have passed through the Bevier coal or its horizon. In this area, the structure has been largely inferred from that of the outcropping rocks. This method is not altogether reliable, because of the irregular manner in which the thickness of the unexposed members varies and because of one or more unconformities. One of these, in the Pleasanton formation, was accompanied by some warping, so that the rocks of the Des Moines group exhibit more folding and faulting than those of the Missouri group. In areas where the Des Moines group outcrops this structure may be visible, but where the Missouri group is at the surface it is usually much less marked.

Many places have not been visited; in many others, deposits of glacial drift or channel sandstone effectually obscure the underlying rocks. In these places very few data could be obtained and the structure contours are based on information obtained in neighboring areas. The contours are necessarily much generalized, because of the small scale of the map, and many small folds could not be shown.

Interpretation of the structure map.—The curve of the contour lines shows the regional strike and dip, the location, length, and direction of the folds, and the degree of folding (vertical displacement as compared with the axes of bounding folds). In a region where the dip is to the northwest, re-entrant angles of the structure contours to the northwest and southeast indicate anticlines and synclines respectively. Closed contours show the location of discontinuous or unevenly developed folds. The vertical displacement may be computed by comparing the altitudes along a line at right angles to the direction of the folds. As an illustration, the Bevier coal at Milan lies at an altitude of 623 feet; in southeastern Putnam County, at 807 feet; and on Chariton River, where it crosses the State line, at 710 feet. The dip on the south limb of the anticline is, therefore, 184 feet in 27 miles; and on the north limb, 97 feet in 10 miles.

STRUCTURE OF THE PENNSYLVANIAN SERIES IN MISSOURI.

DIP AND STRIKE.

In general the dip of the Pennsylvanian is approximately N. 57° W. and the strike N. 23° E. Locally the dip varies considerably, owing to slight folding; and in northern Missouri, north of a line that corresponds roughly with the Omaha branch of the Wabash Railroad, the general dip is to the southwest. This is also true in Iowa, where the line of strike turns to the northwest.

The rocks commonly lie so flat that no dip can be detected excepting when large areas are considered; that is, to the eye, they are usually quite horizontal. From Kansas City north to Hopkins, more than 100 miles, the Hertha limestone dips 280 feet, or about 2.7 feet per mile. From Macon City to Atchison, Kans., the Lexington coal horizon dips 704 feet in about 140 miles or about 5 feet per mile. From Utica, Livingston County, west to St. Joseph, the Hertha dips 7.7 feet per mile. From Princeton to Rockport, along the north boundary of the State, the westerly dip of the Hertha limestone is about 7.5 feet per mile. The dip of the surface rocks in northwestern Missouri appears to be somewhat greater than indicated by the figures given, owing to the thinning of the shale members of the Missouri group to the north.

South of Missouri River the general dip is northwestward. From Clinton to Kansas City the dip is 420 feet or 6.4 feet per mile. From Minden, Barton County, to Kansas City the northerly component of the dip is 550 feet or about 5 feet per mile.

FOLDING.

It has already been mentioned that the general dip can be determined only when very large areas are considered, and that locally the dip may vary considerably. The local structure seems to fall into three classes which, however, are not separated by hard and fast lines.

The first class of structure comprises the low undulations common in the western interior coal field and best shown in coal mines with extensive workings or along creek beds.

The second class is the most striking and includes the small areas, usually two or three to a county, in which the rocks dip rather steeply and are faulted in a few places.

The last, and perhaps most important class from an economic standpoint, includes the folds whose axes trend northwest and southeast. This class of folding, like the regional dip, however, is so gentle that it can be detected only where geologic work covers a comparatively large area. Folds such that the strata are arched (convex upward) are called anticlines and those that are trough-shaped (concave upward) are known as synclines. They are shown on Plate XXIII, which is a preliminary structure map and is subject to revision by future work.

Minor undulations.—Extensive mine workings or good creek-bed outcrops usually exhibit slight changes in the level of the coal bed or outcropping rocks. In mines, these undulations have no definite direction, and it is therefore probable that folding has played a minor role in producing them. The variation in altitude usually amounts to only 30 feet or less in even the larger mines. These minor structural features are probably due to slight irregularities of the surface on which the bed was deposited or to unequal settling of the strata after deposition.

Small areas of marked folding and faulting.—No attempt has been made to show these on the structure map because of their small size, the disturbed areas usually covering only a few acres. In such places, dips of 15 or 20 degrees are common; and near Woodland Mills, Linn County, the rocks are nearly vertical. In a few instances, faulting seems to have taken place. The structural features vary from small symmetrical folds to irregular dips whose inter-relations can be determined only with difficulty. A fault in one of the coal mines at Leavenworth, Kans., is accompanied by a fault breccia in which there are fragments of the coal, limestone, and shale beds affected by the fault.

These disturbances may be explained in two ways. Some may be due to solution of the underlying Mississippian, causing a collapse of the Pennsylvanian strata; others are probably due to the intersection of larger folds, where exceptional strains have resulted in steep dips or faults.

Larger folds.—The approximate location of the axes of the larger folds is shown on the structure map (Plate XXIII). The folds are so gentle, however, that they cannot be said to have definite axes and the lines mapped are, consequently, somewhat generalized. The anticlinal axes are indicated by dashed lines and the synclines by dotted lines.

The larger anticlines named from points through which they pass, are from south to north: the Schell City-Rich Hill; the Ladue-Freeman; the Centerview-Kansas City; the Richmond St. Joseph; the Salisbury-Quitman; the Trenton; the College Mound-Bucklin; and the Kirksville-Mendota; as shown on Plate XXIII.

The dips associated with the larger folds are extremely low as a rule. It is possible, however, that even this slight degree of folding may influence the accumulation of oil and gas, but many other factors must be considered. There must be a source of the oil and gas, there must be a sufficient quantity of water to force them into the anticlines, a porous stratum for their passage, and impervious beds to confine them to the porous stratum. The absence of any one of these conditions would probably render an anticline valueless as an oil and gas bearer.

JOINTING.

All of the limestone and some of the sandstone beds of the region are more or less prominently intersected by vertical joint planes. Most of these may be separated into two principal and two minor sets, but others strike in random directions. Of the principal set, those striking about N. 62° E. are the most common, but those whose direction is about N. 3° W. are scarcely less abundant. Many of the thinner limestones have been cut into rhomboidally-shaped blocks by these joints. The two minor sets strike approximately N. 45° E. and N. 45° W., but vary within a wider range than those of the principal sets. The thicker limestones usually exhibit only the minor jointing.

ALTITUDE OF THE BASE OF THE PENNSYLVANIAN SERIES.

The configuration of northern and western Missouri prior to the deposition of the Pennsylvanian is discussed under "Geologic History." Warping has somewhat changed the aspect of the floor rocks on which the Cherokee shale rests. The pre-Pennsylvanian valley that extended northeast from Atchison

Fig. A. Jointing in Iola limestone near Smithville.

Fig. B. Jointing in Farley limestone near Parkville

MAP SHOWING ALTITUDE OF BASE OF PENNSYLVANIAN.

and Forest City was tilted up to the east so that the base of the Pennsylvanian deposits in Missouri slopes in general from all directions toward a point in Holt County. Here the base of the Cherokee shale lies at a lower altitude (800 feet below sea level) than at any other place known in the State.

The altitude of the base of the Pennsylvanian rocks has been plotted and lines drawn through points of equal altitude as shown in Plate. XXV. By use of this map, the depth to the base of the Cherokee shale can be estimated at any place where the altitude of the surface is known. It should be remembered, however, that the data on which the map is constructed are rather meagre, and the unconformity between the Mississippian and the Pennsylvanian causes changes in the altitude of their contact within very short distances. These two factors may cause errors in places.

CHAPTER VI.

GEOLOGIC HISTORY.

INTERVAL PRECEDING PENNSYLVANIAN SEDIMENTATION.

At the beginning of the Pennsylvanian epoch the area included in the present boundaries of Missouri was above sea level. The highest part was a plateau corresponding roughly with a tongue projecting into the northeastern part of the State a short distance west of the site of the Mississippi. The region now occupied by the main body of the Pennsylvanian was lower, though probably the difference in altitude of the two areas was slight. Meanwhile sediments were being deposited in shallow seas occupying parts of Oklahoma, Arkansas and northern Illinois and the waters were slowly advancing over adjacent land areas.

A description of the topography of Missouri just before Pennsylvanian deposition began must be largely from inference as regards details. Broadly considered, the surface of northwestern Missouri sloped to the northwest about 4 feet per mile to a depression extending from Forest City northeastward. Northwest of this depression the surface apparently rose about 12 feet per mile. Drillings in eastern Harrison County indicate differences in the thickness of Cherokee shale of about 250 feet, due in part at least to the uneven contour of its base, though so great a local variation is uncommon. Along the present margin of the coal-bearing territory early Pennsylvanian topography was one of late maturity, much modified by the effects of solution. The surface rocks were largely soluble limestones containing lenticular layers of insoluble and very resistant chert, which, after the calcareous material had been worn away or dissolved, became concentrated as a talus mantle on the slopes and accumulated in the stream beds. Large underground channels came into existence and many sinks were formed, some of them quite large. Ultimately there was developed a karst topography, similar to that now prevailing in many limestone regions.

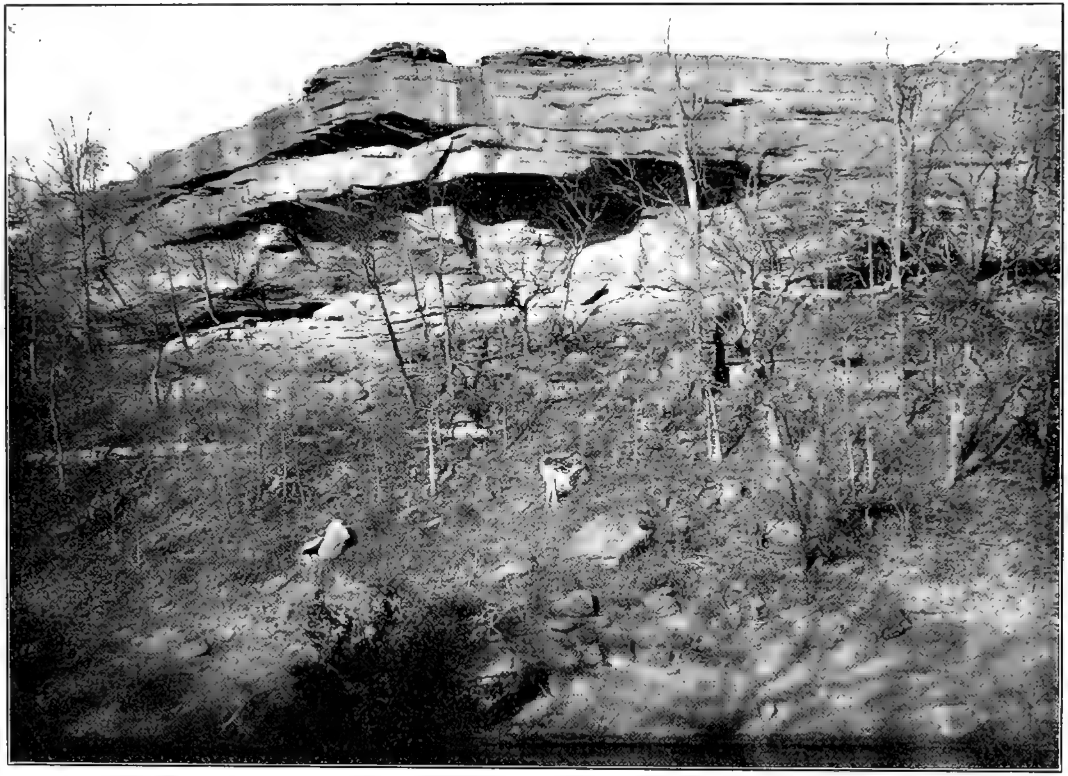
Although a long time elapsed between the emergence of the Mississippian surface and the deposition of Pennsylvanian sediments upon that surface, the earth movements which took place in northern and western Missouri during the interval were not notable. Except in and near the present Ozark country the relationship of the land and sea areas to one another were slowly modified without appreciably altering the approximate horizontality of the Mississippian strata of northern and western Missouri. As a consequence basal Cherokee sediments in widely separated areas rest on formations that are not far apart stratigraphically. In northeastern Missouri they lie, in general, on the St. Louis limestone, and farther southwest along their outcrop zone on the Keokuk and Burlington limestones or their equivalents. Back of the basal outcrop, where the Cherokee shale is now covered with later sediments, the floor of the Cherokee sea was, so far as known, also formed by Mississippian rocks. It is only on and near the Ozarks that Pennsylvanian strata are in contact with pre-Mississippian formations or on strata that are notably tilted.

EARLY TRANSGRESSIONS OF THE SEA.

The Cherokee sea, advancing from the west or southwest, first invaded Missouri in the vicinity of Forest City, Holt County, and soon extended northeast as a long shallow arm through Worth, Harrison, and Mercer counties into Iowa. When about 150 feet of Cherokee sediments had been laid down the arm had broadened out to the southeast so as to embrace Buchanan and Platte counties and, a short time later, Clay, Jackson, and Livingston counties. After the deposition of nearly 400 feet of material in the Forest City area the sea covered practically all of the western tier of counties, except Atchison, and soon extended eastward into Henry, Johnson, Lafayette, Ray, Carroll, Linn, Putnam, and Adair. When the Bevier coal bed was formed, near the beginning of Allegheny time and after the deposition of 580 feet of material at Forest City, some sedimentation had already taken place in all the region now occupied by the main body of the Pennsylvanian and in a fairly large area in which there are now only small patches remaining. The land area had been reduced to an island in southeastern Missouri, with a peninsula projecting into Pike and neighboring counties and a small part of a northern land mass in the extreme northwestern corner of the State. The western sea continued to advance eastward, while an eastern sea occupying most of Illinois advanced westward. Probably by the end of Cherokee time the two seas had joined, submerging practically all of northern Missouri and possibly nearly all of southern Missouri also. No deposition appears to have taken place at this time in the extreme northwestern corner of the State, for the Nebraska City drilling shows less than 100 feet of Des Moines strata, probably of Pleasanton age.

There is still much doubt as to whether the Pennsylvanian sea finally covered practically all of southern Missouri and submerged the Ozarks, though the evidence in hand seems to indicate that a large part of the region was inundated for a comparatively short interval, beginning, probably, near the end of the Cherokee epoch. In nearly all the Ozark counties there are small outliers or pockets of shale, sandstone, and coal in sink holes and other protected situations. Many of these, at least, are of Pennsylvanian age, but were probably deposited before invasion or after the sea receded from the region. The sink holes themselves were certainly formed while above groundwater level and some of them seem to have been deepened while being filled with Pennsylvanian coal and other materials. The remarkably thick pockets of cannel—a coal formed very slowly from only the plant products most resistant to decay—were deposited in stagnant water that was probably fresh.

In addition to the pockets, however, sandstone and shale of Pennsylvanian age are scattered over the Ozarks in small patches capping divides where erosion has not been active. These outliers may have been deposited at the time when the sea covered all or most of Missouri. The thinness of the probable marine Pennsylvanian sediments in all of the Ozarks, however, indicates that the sea may have retreated again in a comparatively short time, probably before the end of the Des Moines epoch. If the Warrensburg and Moberly channels came into existence late in the Pleasanton epoch, as seems probable, a relative uplift of the Ozark took place at that time. Moreover, the differences in the sediments laid down in Missouri and Illinois during the Missouri epoch, so far as known from strata still intact, point toward the presence of a land mass between the two areas during that interval. Some of the sands deposited in parts of the Missouri epoch are also most easily explained by postulating a land mass in southern Missouri. The overlap of



Basal sandstone of Pennsylvanian series, Monegaw Springs, St. Clair County.

Des Moines strata toward the west and the probable derivation of some early Des Moines sediments from an Ozark land mass, on the other hand, seem to show that the Ozarks were above sea until late in the Cherokee epoch.

SEDIMENTATION DURING DES MOINES EPOCH.

As the Cherokee sea advanced upon the old land surface its first act was to rearrange the loose weathered materials and to fill up existing valleys and caverns. It may be that much of the basal sandstone along the southwestern outcrop and under cover farther northwest is only slightly rearranged residual matter, and that the thick basal fire clays of east-central Missouri had a similar origin. The deposit to which Smith applied the name Saline Creek cave-conglomerate is the result of the filling of underground caverns, in many cases before their submergence. True basal conglomerates are rare and essentially local, showing that the drainage from the Ozark land mass had been sluggish for a long time before Cherokee sedimentation began.

Before the formation of the Tebo and Bevier coal beds Cherokee deposits consisted almost entirely of clay and sands laid down in a shallow sea that occasionally withdrew while peats were formed in low-lying swamps. The earlier deposits were laid down in submerged valleys and more or less disconnected bays, and, consequently, varied greatly from place to place. About the time the Tebo coal was formed conditions became more uniform, and during the later Cherokee deposition was slower and remarkably similar over large areas. The coal swamps were all of the coastal type and were destroyed by invasions of salt or brackish water that were often simultaneous over large areas. Several of the coals bear very thin persistent partings, formed during temporary submergences that killed the plants but brought in very little sediment.

During the later part of the Cherokee epoch several thin marine limestones were formed, closely associated with coal beds. There seem to have been cycles of sedimentation similar to those in Illinois which are described by Udden.[1] The cycles began with (1) the growth of coal-forming plants; followed by (2) an invasion of the sea which killed the vegetation,

[1]Udden, J. A., Geology and mineral resources of the Peoria quadrangle, Illinois: U. S. Geol. Survey Bull. 506, pp. 47-50, 1912.

but was favorable to marine animal life; then (3) an increase in sediment killed most of the limestone-forming animals, and the basin filled to the surface with muck and sand; and finally (4) soil was formed and plant life began to flourish. In Missouri a second interval favorable to marine life often intervened between stages (3) and (4), so that the soil and plants of the final stage were laid upon a thin limestone. Acids derived from plant material passed down and dissolved parts of the underlying limestone, giving it the nodular appearance characteristic of many of the "bottom rocks" of coal beds.

During Henrietta time a greater proportion of limestone was produced. These beds were also marine and some of them were probably huge fringing reefs and were co-extensive with at least the region now underlain by the Henrietta formation in Missouri.

Pleasanton time was characterized by the deposition of muds and sands under rapidly changing conditions, though some limestone and a few coal swamps were formed. After about 100 feet of sediment had been laid down, there was probably a relative uplift sufficient to cause withdrawal of the sea from most of Missouri. The uplift was greater in the Ozark region and near the Mississippi than elsewhere, and swift streams flowed from these higher lands to the north and west. Several deep, narrow valleys characteristic of a region in early topographic youth were excavated, and part of the deposits of Henrietta and early Pleasanton time were removed in places. During the last of the Pleasanton epoch northern and western Missouri subsided and sand and mud were spread over the recently exposed surfaces, most of which had been only slightly eroded.

SEDIMENTATION DURING MISSOURI EPOCH.

The Missouri group seems to have been deposited under conditions which alternated between those of quiet waters, which permitted the growth of marine invertebrates but excluded clastic sediments to a large degree, and those of unsettled and disturbed waters in which sandstones and shales were deposited. From time to time the more unsettled conditions changed during short intervals in which lenticular coal or limestone beds were formed. While quiet waters prevailed and calcareous materials were conspicuous among the sediments, conditions were unfavorable for extensive plant growth. Even at other times coal-forming plants succeeded in establishing themselves only for relatively short intervals and, with one or two exceptions, in comparatively small swamps. The intervals of limestone deposition, on the whole, grew shorter as time progressed.

One of the notable features of deposition during the Missouri epoch was the repetition of an alternating succession of limestones and thin shales with thicker shales and sandstones. Almost exactly similar conditions of sedimentation appear to have recurred intermittently over wide areas. There is a striking similarity in the Plattsburg and Stanton, Oread, and Deer Creek limestones and to a less degree in the Lecompton, Topeka and Howard, and the Tarkio and cap rock limestone of Nyman coal. In each case the sections show only minor variations from the following succession:

1. Limestone, flaggy; a thin bed (at top).
2. Shale, drab; a few feet.
3. Limestone, gray, thin-bedded; a thick bed.
4. Shale, black, slaty.
5. Limestone, dark gray, even-bedded; 1 or 2 feet.
6. Shale, drab.
7. Limestone, blue (at base).

In the Plattsburg and Stanton, Oread, and Deer Creek members this succession is typically shown. In the other cases mentioned the place of the dark-gray, even-bedded limestone (5) seems to be taken in some areas by coal, and the limestone (3) is much thinner.

The clastic members have certain resemblances, which, however, are not nearly so striking as those just mentioned. Most of them contain sandstones that vary in apparent stratigraphic position within short distances, and include limestones that do not maintain uniform thicknesses.

DEFORMATIONS.

From the beginning to the end of Pennsylvanian time in Missouri earth movements in the region now occupied by the series were relatively slow, simple, and uniform. In general there was a long-continued subsidence of the region, broken by periods of stability and with, perhaps, relative uplift of adjacent land areas during several intervals. The uniformity of the subsidence is shown by the persistence in thickness, areal extent, and character of most of the members of most of the formations. The periods of stability culminated in the formation of the wide-spread coal beds, after sedimentation had filled the sea and caused its withdrawal, and ended when a renewal of subsidence again let in the saline waters, killing the coal plants.

The relative uplift of neighboring land areas is indicated by the periodic recurrence of irregular deposition and a comparatively large proportion of arenaceous sediments. In most Pennsylvanian formations the strata are remarkably persistent and regular, but in the Pleasanton, Douglas, and part of the Cherokee formations, and in the Lane, Severy, Scranton and a few other members, the strata are variable. An influx of sands was usually caused, probably, by changes in the currents of the shallow sea, in the direction of drainage lines on neighboring land masses, or in the derivation of sediments. During the Pleasanton and Douglas epochs, however, the phenomena were somewhat more complex. As stated more fully on previous pages, there is evidence that the sea may have withdrawn from all or part of Missouri in both Pleasanton and Lawrence time while long and rather deep channels were formed by sub-aerial erosion. These changes appear to have been effected by slight tilting and folding in northern and western Missouri as well as by differential uplift of the Ozark region.

After the close of the Pennsylvanian there were two periods of folding. The first of these resulted in the blocking out of the main broad features of the present structure, namely the monoclinal dip to the west in north Missouri and to the northwest in the west-central part of the State. The second period of folding caused the formation of narrow and comparatively sharp anticlines and associated synclines trending northwest-southeast and markedly parallel throughout the State. The structural features are more fully described in the preceding chapter.

The following records are representative of the deeper drilling that has been done in the region underlain by the Pennsylvanian. They indicate the general nature, succession, and variation of the formations in different parts of the field. The description of the Forest City well is made from a study of the core which is preserved at the headquarters of the Bureau of Geology and Mines.

LOG OF DIAMOND DRILL HOLE ON W. F. DAVIS' FARM NEAR FOREST CITY, MISSOURI. DRILLED IN 1901.

Stratum.	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Pleistocene series:				
Sandy clay, no core (loess)	65		65	
Clay and bowlders, no core (drift:)	10		75	
Pennsylvanian series:				
Shawnee formation:				
Tecumseh shale:				
Clay shale (no core)	15		90	
Lecompton limestone:				
Limestone, dark-gray, argillaceous, very fossiliferous, especially Fusulina; passes into shale	2	4	92	4
Shale, greenish, very calcareous, fossiliferous.	4	4	96	8
Limestone, gray, fine-grained, much calcite, partings shaly, very fossiliferous, especially Fusulina; becomes shaly at base, not sharply separated from underlying shale	4	7	101	3
Shale, gray, calcarcous at top, black and slaty at base; also some dark layers near middle	3	3	104	6
Shale, clayey		2	104	8
Limestone, dark-gray, composed chiefly of Fusulina, giving core a mottled appearance		9	105	5
Limestone, gray, tinged with green in places; fine-grained, argillaceous; has a few calcite crystals; at top grades into a dark clayey shale a few inches thick	10	4	115	9
Shale, grayish-green; considerably darker at the base; slightly calcareous in places	3	10	118	7
Limestone, soft, argillaceous		10	119	5
Shale, green, very fossiliferous		2	119	7
Limestone, light-colored, compact, fine-grained, earthy to sugary, fossiliferous; grades to shale at the base	4	10	124	5
Kanwaka shale:				
Shale, greenish-gray, dark-gray at top; pyritiferous, some fossils	4	7	129	
Shale, gray, considerable mica and some pyrite in upper four feet; few fossils, upper part calcareous in streaks and banded with sand; middle not calcareous; bottom calcareous; lower foot has a nodular texture	12	3	141	3
Limestone, dark, very shaly at top where it grades into above; lower part gray; alternate light and dark patches bounded by fossils; pyritiferous	3	2	145	5
Shale, gray; calcareous at top and bottom. Ten inches from top is a hard bituminous bowlder of blackish-brown color, with a thin one-half inch seam of coal on each side	1	11	147	4
Shale, greenish-colored; upper portion calcareous; slightly calcareous near the bottom	11	2	158	6

LOG OF DIAMOND DRILL HOLE ON W. F. DAVIS' FARM NEAR FOREST CITY, MISSOURI. DRILLED IN 1901—Continued.

Stratum.	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Pennsylvanian series—Continued.				
Douglas formation:				
Oread limestone:				
Limestone, dark-gray, granular, medium-grained, argillaceous, sub-oölitic, the fossil fragments being surrounded by concentric bands, fossiliferous	2	8	161	2
Shale, gray, calcareous and fossiliferous		5	161	7
Limestone, dark-gray, very fossiliferous; medium-grained, very irregular bedding planes and diagonal jointing; has several dark bituminous shaly partings	6	8	168	3
Limestone, dark-gray upper eight feet; remainder light-gray, irregular shaly partings, fossiliferous, pyritiferous, calcite lining and filling fossil cavities, stylolites	21		189	3
Shale, first foot is light-greenish colored and calcareous grading to black with thin lighter-colored calcareous bands; small crystals of pyrite	3	10	193	1
Limestone, gray, with shaly bands, numerous fossils	2	6	195	7
Shale, gray and greenish, becoming clayey toward base	2	7	198	2
Clay shale, light-green, calcareous	8	8	206	10
Limestone, greenish, soft, shaly, nodular	2	2	209	
Limestone, gray, with much green shale grading to green shale; very fossiliferous, especially where shaly	4	6	213	6
Lawrence shale:				
Shale, green, calcareous	1	5	214	11
Clay shale, dark gray		2	215	1
Clay shale, green, calcareous, partly purple at bottom	5		220	1
Clay shale, dark purplish, mottled with green, calcareous	1	3	221	4
Shale, green, with purplish bands; sandy, slightly calcareous	11	3	232	7
Limestone, mottled gray and brown; compact, with occasional irregular parting planes of shale, giving a brecciated appearance; contains much disseminated calcite (Amazonia limestone)	4	11	237	6
Shale, dark-gray, arenaceous, thinly laminated, having a greenish cast in places; some mica; pyrite in rather large pieces	10	4	247	10
Shale, dark-gray, micaceous	2	4	250	2
Sandstone and sandy shale interbedded; light and dark banded, thin bedded, micaceous, pyritiferous, fossiliferous	77	8	327	10
Shale, gray, pyritiferous, slightly calcareous in places, especially toward bottom	9		336	10
Limestone, soft, very fossiliferous, argillaceous	1		337	10

LOG OF DIAMOND DRILL HOLE ON W. F. DAVIS' FARM NEAR FOREST CITY, MISSOURI. DRILLED IN 1901.—Continued.

Stratum.	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Pennsylvanian series—Continued.				
Lawrence shale—Continued.				
Shale, fine-grained, very calcareous	5	5	343	3
Shale, green, mottled near the base; very calcareous, due to large irregular patches of limestone	4	7	347	10
Iatan limestone:				
Limestone, gray, nodular, imbedded in green, calcareous shale	9		356	10
Weston shale:				
Clay, gray and shaly at top; greenish, with purple layer at base	2	4	359	2
Shale, in part clayey, greenish-gray, micaceous, especially towards the bottom	8	2	367	4
Shale, blue, green, brown and nearly black; calcareous, slightly micaceous in places; middle part of bed somewhat banded by hard brown ferruginous layers one-half inch thick; well laminated except at top, where it is clayey	39	10	407	2
Shale, dark-blue, sandy and pyritiferous new top; contains occasional hard brown ferruginous bands	10	11	418	1
Lansing formation:				
Stanton limestone:				
Limestone, medium-grained, argillaceous, gray with light-colored areas around a dark nucleus; very shaly at top; small amount of calcite	5	4	423	5
Limestone, dark-gray, very argillaceous, arenaceous, fossiliferous, brachiopods most common	3	1	426	6
Clay shale, greenish	2	1	428	7
Limestone, light-colored, mainly fine-grained; very argillaceous, especially at the top and bottom. About four feet from the top are stylolites and drusy cavites lined with calcite crystals. Fossiliferous, especially at the bottom. This bed consists of alternating dark and light bands, due to the presence of numerous fossils, mainly Fusulina	7	2	445	9
Shale, black	1	3	447	
Shale, dark-gray, calcareous, black near the base; black streak occurs about two feet ten inches from the top; lower part fossiliferous	7	2	454	2
Limestone, buff and compact at top, with calcite crystals at partings; after two feet grades to a more argillaceous type which has a dark color. The light-colored portion is thoroughly crystalline and fossiliferous	3	2	457	4

LOG OF DIAMOND DRILL HOLE ON W. F. DAVIS' FARM NEAR FOREST CITY, MISSOURI. DRILLED IN 1901—Continued.

Stratum.	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Pennsylvanian series—Continued.				
Vilas shale:				
Shale, dark-blue; very calcareous, contains one or two bands of limestone	10		467	4
Shale, dark-green		8	468	
Shale, greenish, mottled with gray, very calcareous	1	5	469	5
Plattsburg limestone:				
Limestone, light and dark-gray, fine-grained, argillaceous, having a granular texture. Portions of this bed resemble white "cotton rock," which alternates with thin bands of dark, shaly limestone	4	9	474	2
Shale, black, calcareous		11	475	1
Limestone, gray, fine-grained, argillaceous at top and bottom. Includes irregular bands of dark argillaceous limestone at different places; the shaly bands are especially fossiliferous; contains much disseminated calcite in middle portion	9	6	484	7
Shale, gray to dark-gray, calcareous, lower 13 inches practically argillaceous limestone	1	10	486	5
Limestone, dark-gray, argillaceous; increasingly argillaceous at top and bottom; lower half very fossiliferous	5	9	492	2
Limestone, light-gray, fossiliferous, medium-grained, sub-oölitic, contains some disseminated calcite	2	6	494	8
Shale, greenish		7	495	3
Limestone, light-gray, fine-grained, having much the appearance of cotton rock	1	8	496	11
Lane shale:				
Shale, dark-blue, fossiliferous	2	3	499	2
Limestone, very fossiliferous, argillaceous; rather coarse granular texture		11	500	1
Limestone, dark-gray argillaceous, fossiliferous; contains 3-inch band of very dark calcareous shale	3	5	503	6
Shale, dark, calcareous, containing two 3-inch bands of gray argillaceous limestone	3	4	506	10
Shale, light greenish-gray	1	6	508	4
Shale, gray, calcareous; upper 14 inches is practically an argillaceous limestone	3	4	511	8
Shale, dark grayish-green, calcareous and arenaceous; about 16 inches from base is 10 inches of argillaceous, gray, fossiliferous limestone	14	6	526	2
Shale, light and dark-gray, in places banded, arenaceous at top, the lower 3 feet 6 inches calcareous and very fossiliferous	16	1	542	1

LOG OF DIAMOND DRILL HOLE ON W. F. DAVIS' FARM NEAR FOREST CITY, MISSOURI. DRILLED IN 1901—Continued.

Stratum.	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Pennsylvanian series—Continued.				
Kansas City formation:				
Iola limestone:				
Limestone, light-gray, somewhat coarsely crystalline, shaly at top and at intervals throughout. Upper part contains few small drusy cavities lined with calcite. In some places a fresh fracture exhibits a brownish and grayish mottled appearance; fossils prominent	11		553	3
Chanute shale:				
Limestone, very argillaceous, alternating with shale, very calcareous; fossiliferous, especially the shale. The limestone bands are light-gray and the shale bands are dark-gray to almost black (Raytown limestone)	5	8	558	11
Shale, upper part dark, almost black; 14 inches of this is very bituminous; the remainder is chiefly a greenish color and calcareous throughout. There are two 3-inch bands of argillaceous limestone in this bed; fossiliferous	7	1	566	
Shale, gray and greenish-gray, calcareous, clayey; near base is 16-inch bed containing irregular-shaped limestone nodules	8	2	574	2
Limestone, gray, argillaceous nodules embedded in greenish shale; fossiliferous; has a coarse granular texture partly crystalline and becomes more solid toward base (probably Cement City limestone)	4	1	578	3
Shale, green, calcareous, especially near top and bottom; near base are irregularly-shaped limestone nodules	4	2	582	5
Drum limestone:				
Limestone, gray, slightly argillaceous; semi-crystalline sugary texture; irregular wavy shaly bedding planes	2	11	585	4
Limestone, very argillaceous; has a mottled appearance due to the extremely irregular manner in which the shale and limestone are intermingled; limestone, light-gray; shale, greenish-gray; near the top is a 6-inch band of calcareous shale	5	7	590	11
Cherryvale shale:				
Shale, gray, calcareous; limestone occurs in irregular masses	1	11	592	10
Limestone, shaly	1	11	594	9
Shale, dark, bituminous, calcareous		10	595	7
Limestone, mottled light and dark-gray by irregular distribution of shale partings	1	3	596	10
Shale, dark-gray, calcareous, bituminous, alternating with very argillaceous limestone	6	8	603	6

LOG OF DIAMOND DRILL HOLE ON W. F. DAVIS' FARM NEAR FOREST CITY, MISSOURI. DRILLED IN 1901—Continued.

Stratum.	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Pennsylvanian series—Continued.				
Cherryvale shale—Continued.				
Shale, dark-colored, bituminous, calcareous..	3		606	6
Shale, alternating with bands of dark-gray, argillaceous limestone; fossiliferous; becomes more calcareous at base grading to nodular limestone; sharply separated from underlying limestone.............	14	1	620	7
Winterset limestone:				
Limestone, light-gray, compact, crystalline, having a medium-grained ground-mass through which are distributed small calcite crystals, evidently a replacement of fossils	7		627	7
Shale, dark, calcareous..................	4	11	632	6
Shale, greenish-gray, calcareous toward the top...............................	2	3	634	9
Limestone, light-gray, medium-grained, oölitic, fossiliferous; finely porous; contains pink barite and pyrites on what appears to be a vertical joint; texture similar in many respects to that at 627-7	4	7	639	4
Limestone, fine-grained; similar to above; in 3 beds; less porous and shows less oölitic texture; lower 18 inches argillaceous and fossiliferous......................	4	4	643	8
Limestone, fine-grained; oölitic and fossiliferous; Fusulina common..............		10	644	6
Limestone, light-gray, argillaceous, alternating with dark-gray calcareous shale, fossiliferous; limestone fine-grained; from 644-6 to 646-2 and from 652-6 to 656-6 limestone predominates; these limestones contain small nodules of black fossiliferous chert........................	14	6	659	
Limestone, gray, with thin partings of dark shale; in places the limestone is colored brownish with what appears to be bituminous material; cherty, calcite, very fossiliferous; darker and more shaly toward base...............................	10	6	669	6
Galesburg shale:				
Shale, black, very bituminous; calcareous, especially at top......................	3	1	672	7
Shale, gray, clayey; calcareous at top and bottom.............................	2	7	675	2
Bethany Falls limestone:				
Shale, green, calcareous, passes into limestone nodules embedded in shale; upper part of bed and lower part chiefly limestone; grades into next bed below........	3	3	678	5

LOG OF DIAMOND DRILL HOLE ON W. F. DAVIS' FARM NEAR FOREST CITY, MISSOURI. DRILLED IN 1901—Continued.

Stratum.	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Pennsylvanian series—Continued.				
Bethany Falls limestone—Continued.				
Limestone, gray, showing light and dark mottled appearance; parting planes are extremely irregular, giving the surface a brecciated appearance; lower portion contains considerable shale mixed through the limestone, which shows stylolites; lower portion fossiliferous	7	4	685	9
Limestone, oölitic, very hard, containing many small cavities; stylolites numerous and prominent	2	10	688	7
Limestone, gray, rather fine-grained, with disseminated calcite crystals; upper part somewhat pyritiferous; shaly layers, fossiliferous	9	7	698	2
Ladore shale:				
Shale, dark, bituminous, calcareous	3	5	701	7
Limestone, very argillaceous; grading to shale above and below		7	702	2
Shale, greenish, calcareous. Slickensides	5	4	707	6
Limestone, argillaceous		10	708	4
Shale, containing irregular nodules of limestone	1	2	709	6
Limestone, argillaceous		6	710	
Shale, calcareous		6	710	6
Limestone, argillaceous		4	710	10
Shale, containing irregular nodules of limestone		10	711	8
Shale, dark-green, calcareous		6	712	2
Hertha limestone:				
Limestone, gray, with shaly partings, occasional cavities lined with calcite crystals; fossiliferous styolites	12	11	725	1
Pleasanton and Henrietta formations:				
Shale, blue-gray, calcareous, sandy, fossiliferous, pyritiferous	1	6	726	7
Sandstone, dark and light bands, shaly, pyritiferous, very calcareous	4	11	731	6
Coal, contains fossil plants (Ovid)		6	732	
Clay, blue-gray, arenaclous; darker and carbonaceous at top; shaly at base	2	4	734	4
Sandstone, grayish, fine-grained, calcareous; thin-bedded at top; more massive in lower portion; pyritiferous and contains numerous small pebbles near top; micaceous between 737-10 and 742-10	8	6	742	10
Sandstone, blue, argillaceous, fine-grained, pyritiferous, micaceous	4	11	747	9
Sandstone, greenish-gray, rather coarse-grained, having a spotted appearance; calcareous, fossiliferous, pyritiferous, micaceous in places	4	5	752	2

LOG OF DIAMOND DRILL HOLE ON W. F. DAVIS' FARM NEAR FOREST CITY, MISSOURI. DRILLED IN 1901.—Continued.

Stratum.	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Pennsylvanian series—Continued.				
Pleasanton and Henrietta formations—Continued.				
Shale, grayish-blue; between 766-9 and 771-9 calcareous and increasingly so toward the base	19	7	771	9
Limestone, dark-gray, argillaceous, fossiliferous, hard	3	5	775	2
Shale, dark-colored, calcareous, arenaceous, pyritiferous, fossiliferous		5	775	7
Shale, green, sandy, clayey; calcareous in places, especially at base	3	9	779	4
Limestone, light-colored; argillaceous chiefly at top and bottom; fine-grained, compact, with small disseminated calcite grains	1	9	781	1
Shale, green, upper half calcareous	1	3	782	4
Clay and shale, blue, green, black and brown calcareous, arenaceous, bituminous at top and a bituminous bed lower in the section	9	2	791	6
Limestone and shale, nodular; limestone gray; shale brownish-gray; shows fine cross fractures which have been recemented with calcite	3	2	794	8
Shale, greenish, calcareous, with several thin irregular bands of limestone	4	5	799	1
Limestone, somewhat crystalline; several thin partings of shale	1	5	800	6
Sandstone, light-green, fine-grained, argillaceous; from 802 to 810 dark-green and more shaly; micaceaus and very fine-grained	9	6	810	
Shale, gray, banded with red and green	2	6	812	6
Clay, dark-gray	2	8	815	2
Limestone, greenish, mottled, argillaceous, passing into a very calcareous shale in lower two feet; fossiliferous	5	4	821	6
Shale, light to dark-gray, and nearly black; in part clayey	3	8	825	2
Clay shale, greenish	1	4	826	6
Shale, greenish, fossiliferous, passing into greenish-gray, argillaceous limestone	3	5	829	11
Shale, light to dark-gray; in part clayey	3	2	833	1
Shale, greenish, very calcareous, fossiliferous, passes in places to fossiliferous, argillaceous limestone	2	11	836	
Cherokee shale:				
Shale, black, with a thin layer of coal (Lexington) at bottom		10	836	10
Clay shale, dark-gray at top, light-gray toward base	6	7	843	5
Limestone, gray, argillaceous; grading to shale above and below; fossiliferous	5	7	849	
Clay, light-gray, calcareous	2		851	

LOG OF DIAMOND DRILL HOLE ON W. F. DAVIS' FARM NEAR FOREST CITY, MISSOURI. DRILLED IN 1901—Continued.

Stratum.	Thickness.		Depth	
	Ft.	in.	Ft.	in.
Pennsylvanian series—Continued.				
Cherokee shale—Continued.				
Shale, green, micaceous, arenaceous	1	4	852	4
Shale, reddish-brown, arenaceous, micaceous, with two thin greenish beds, slickensided	3	7	855	11
Shale, slaty, dark-gray, arenaceous, micaceous in places: calcareous, especially in the last 5 feet	10		865	11
Limestone, medium dark-gray, fine-grained, argillaceous at the top, arenaceous at the bottom. Very fossiliferous, brachiopods and a species of Chonetes resembling *granulifer* especially common; calcite crystals	2		867	11
Sandstone, dark bluish-gray, fine-grained, argillaceous, micaceous; calcareous at top	5	5	873	4
Shale, black, slaty; rather arenaceous at top	7	8	881	
Shale, like above. From 883 to 887 more calcareous and fossiliferous and less slaty; two feet from the base occurs about 8 inches of very bituminous shale; calcite in fracture planes	8		889	
Coal, bony; has white scale on vertical faces (Summit)		4	889	4
Sandstone, hard, gray, rather coarse-grained, with irregular very thin bands of carbonaceous matter; slightly calcareous, pyritiferous	4	4	893	8
Sandstone, fine-grained, very argillaceous, pyritiferous	1	3	894	11
Shale, dark-gray, arenaceous, upper few inches fossiliferous	3	4	898	3
Clay, calcareous	1		899	3
Limestone, compact, fine-grained, fossiliferous, argillaceous	2	9	902	
Limestone, dark-colored, very argillaceous, fossiliferous, grades into shale, brachiopods common	6		908	
Shale, gray and black, alternating; calcareous, especially the gray bands. The middle 4 feet and a six-inch band near the top are very bituminous; in general becoming darker and more slaty toward base	8	10	916	10
Clay, gray	3		919	10
Limestone, greenish, argillaceous	2	2	922	
Shale, green, calcareous; slightly arenaceous	4	2	926	2
Limestone, light-gray, very argillaceous; occasional calcite crystals	2	3	928	5
Shale, green to black, slaty, calcareous	1	6	929	11
Limestone, fine-grained, very carbonaceous, argillaceous		8	930	7
Shale, dark; many very thin argillaceous limestone bands; about 6 inches at the top is black, slaty, and carbonaceous	3		933	7

LOG OF DIAMOND DRILL HOLE ON W. F. DAVIS' FARM NEAR FOREST CITY, MISSOURI. DRILLED IN 1901—Continued.

Stratum.	Thickness. Ft.	Thickness. in.	Depth. Ft.	Depth. in.
Pennsylvanian series—Continued.				
Cherokee shale—Continued.				
Shale, greenish, clayey, almost black at the top, calcareous, arenaceous	3		936	7
Sandstone, fine-grained, argillaceous, calcareous in places, pyritiferous	7	5	944	
Shale, green, arenaceous, micaceous; the upper 7 feet 4 inches practically argillaceous sandstone. Many lamellibranchs and brachiopods	17		961	
Shale, dark grayish-blue, almost black in places; very fine-grained; slightly arenaceous, pyritiferous and contains many hard brown calcareous spots; fossiliferous	23	6	984	6
Limestone, brownish-black; very fossiliferous, carbonaceous, argillaceous, arenaceous *Productus cora* especially abundant	1	8	986	2
Coal, rotten (Bedford)		4	986	6
Shale, gray, pyritiferous; contains pieces of carbonized wood; at the base arenaceous and micaceous	6	9	993	3
Sandstone, micaceous; increasingly calcareous toward the base	1	3	994	6
Coal, pyritiferous (Bevier)	1	2	995	8
Shale, bluish-gray, micaceous, carbonaceous in upper part	1	4	997	
Sandstone, gray, soft, argillaceous, carbonaceous in places; pyritiferous, contains numerous hard brown ferruginous beds throughout; micaceous and shows a finely laminated structure; grades into a shale near the bottom; fossils are numerous, among which are plants	7		1004	
Shale, dark-blue to black; has several very hard, brown, ferruginous bands usually less than one-half inch thick; the last six inches is very carbonaceous	7	6	1011	6
Shale, greenish to brown, fossiliferous, with calcareous bands and nodules	18	1	1029	7
Shale, black, slaty, carbonaceous	1		1030	7
Limestone, greenish-gray, compact, argillaceous, earthy texture		8	1031	3
Shale, slaty, calcareous and carbonaceous	1	10	1033	1
Limestone, dark, bituminous, fossiliferous, argillaceous; has dark-gray fucoidal markings		11	1034	
Shale, black, slaty, carbonaceous	1	1	1035	1
Limestone, brownish-black, compact, argillaceous, fossiliferous		4	1035	5
Shale, black, slaty, carbonaceous	1	9	1037	2
Limestone, brownish-black, compact, argillaceous, fossiliferous		8	1037	10
Shale, black, slaty, carbonaceous	2	2	1040	
Coal (Tebo?)	1	3	1041	3

LOG OF DIAMOND DRILL HOLE ON W. F. DAVIS' FARM NEAR FOREST CITY, MISSOURI. DRILLED IN 1901—Continued.

Stratum.	Thickness.		Depth.	
Pennsylvanian series—Continued.	*Ft.*	*in.*	*Ft.*	*in.*
Cherokee shale—Continued.				
Clay, dark-gray; becoming sandy below and containing numerous small pebbles and grains of quartz; pyritiferous and fossiliferous	2		1043	3
Clay, light-gray, sandy	2		1045	3
Sandstone, fine-grained, greenish, very argillaceous, shaly in places; very pyritiferous and slightly calcareous at the top; becomes micaceous in lower part	6	3	1051	6
Shale, rather dark-gray, arenaceous with numerous very irregular hard brown ferruginous concretions and alternate dark and light bands	4	3	1055	9
Shale, black, carbonaceous	3	8	1059	5
Coal	1		1060	5
Shale, dark-gray, clayey, carbonaceous, slickensided		4	1060	9
Sandstone, gray, fine-grained, micaceous, fossiliferous	4		1064	9
Shale, black, slaty toward bottom	5	8	1070	5
Coal		9	1071	2
Shale, gray, arenaceous; clayey at top; contains irregular calcareous patches and hard brown ferruginous nodules and bands; very pyritiferous, fossiliferous and slickensided	8	9	1079	11
Shale, grading from dark-green to black; calcareous; micaceous toward the bottom	2	7	1082	6
Clay, brownish, very sandy; grading to sandstone below	2	4	1084	10
Sandstone, light-colored, greenish-tinted; micaceous, with irregular brown calcareous nodules. The upper 12 or 15 inches are very argillaceous, being a gradation from the overlying bed	10		1094	10
Sandstone, dark-grayish to greenish, shaly, somewhat micaceous	2	4	1097	2
Sandstone, very micaceous		10	1098	
Sandstone, shaly. The shale in this bed occurs in thin wavy laminae separating the sand into thin bands. Very micaceous, with alternate gray and brown color	7	2	1105	2
Sandstone, like above, except an increase in thickness of shale bands	5	6	1110	8
Shale, sandy in part; pyritiferous and calcareous; micaceous	9	4	1120	
Shale, dark bluish-gray	7	7	1127	7
Shale, black; one foot from the top is a 14-inch band of dark-gray shale, the remainder being chiefly black with irregular hard brown areas at intervals. Somewhat calcareous in places and in others very carbonaceous; fossiliferous	13	5	1141	

LOG OF DIAMOND DRILL HOLE ON W. F. DAVIS' FARM NEAR FOREST CITY, MISSOURI. DRILLED IN 1901—Continued.

Stratum.	Thickness. Ft.	in.	Depth. Ft.	in.
Pennsylvanian series—Contioued.				
Cherokee shale—Continued.				
Coal, pyritiferous		9	1141	9
Clay, gray, pyritiferous	4	3	1146	
Shale, brown, iron-stained, very hard		5	1146	5
Sandstone, dark, argillaceous; slickensided	1	2	1147	7
Shale, dark, pyritiferous; arenaceous at top	2	5	1150	
Shale, black, very carbonaceous		3	1150	3
Shale, dark-colored, clayey, arenaceous, with numerous hard brown ferruginous bands and nodules	7	10	1158	1
Clay, light-colored, sandy	1	11	1160	
Sandstone, light-colored, medium-grained; discolored in irregular patches by brown ferruginous material	4	8	1164	8
Sandstone, bluish-gray, finely-banded, very argillaceous, micaceous; lower part speckled with brown grains	3	6	1168	2
Shale, dark-colored, arenaceous at top	2	6	1170	8
Sandstone, light-colored, fine-grained, micaceous	1	10	1172	6
Shale, dark-gray, containing some mica; slickensided	1	3	1173	9
Shale, black, with many irregular hard, brown, ferruginous masses	2	4	1176	1
Shale, black, slaty, pyritiferous	6	5	1182	6
Sandstone, very argillaceous		6	1183	
Shale, dark-blue to nearly black, arenaceous, numerous brown, ferruginous bands, micaceous and pyritiferous	3	4	1186	4
Wasted core	2	2	1188	6
Sandstone, brownish-black, hard, calcareous, fossiliferous	2	3	1190	9
Shale, black, slaty, hard. calcareous, characterized by alternating thin gray and black bands; some hard, iron-stained bands, also pyritiferous; grades into shale below	16		1206	9
Shale, light grayish-green; contains sandstone in bands, the amount of sand increasing toward the base; pyritiferous	7	5	1214	2
Sandstone, light-gray, fine-grained, slightly micaceous	1	6	1215	8
Shale, greenish-gray; contains small sand-like granules which appear as black specks on the surface. These are thought to be iron carbonate, partly or completely altered to iron oxide. This shale has a rough granular texture as a result of the disseminated particles of siderite		10	1216	6
Sandstone, greenish, argillaceous; contains granules similar to those in shale above, also iron-stained in irregular areas	1	4	1217	10

LOG OF DIAMOND DRILL HOLE ON W. F. DAVIS' FARM NEAR FOREST CITY, MISSOURI. DRILLED IN 1901.—Continued.

Stratum.	Thickness. Ft.	Thickness. in.	Depth. Ft.	Depth. in.
Pennsylvanian series—Continued.				
Cherokee shale—Continued.				
Shale, greenish-gray, arenaceous at the top; grades into a dark-gray non-arenaceous shale; slickensided	4	6	1222	4
Sandstone, light bluish-gray, fine-grained; calcareous and argillaceous in places; micaceous. Brown siderite particles are prominent and in the last 18 inches form rather large masses	5	3	1227	7
Shale, black, slaty, carbonaceous, with thin coal seams	2		1229	7
Sandstone, gray, fine-grained, micaceous; has bluish argillaceous bands near the bottom. Fossiliferous; numerous plant remains. Small brown granules similar to those observed above	6	9	1236	4
Shale, dark-bluish; lower 5 inches black, above which are seven inches of pyritiferous shale	3	8	1240	
Shale, dark-blue to black, with hard, brown bands; pyritiferous	11	4	1251	4
Coal		5	1251	9
Clay, dark-gray, sandy, with coal partings		4	1252	1
Sandstone, fine-grained, micaceous; has thin coal partings usually diagonal to the core, fine brown granules. Near the top the color is a light-gray, but becomes a dark-bluish gray, and finely laminated toward the base	5	11	1258	
Shale, black, bituminous, slaty, with hard, brown layers	5	5	1263	5
Coal, rotten		3	1263	8
Sandstone, gray, fine-grained; several thin layers, clayey, showing brown granules, carbonaceous and pyritiferous in places	5	10	1269	6
Shale, grayish, clayey, arenaceous; slickensided	2	3	1271	9
Shale, clayey, carbonaceous, arenaceous		3	1272	
Sandstone, argillaceous, increasingly shaly at top and bottom; has a finely-banded structure and contains brown ironstone concretions; color dark bluish-gray, due to carbonaceous material; plant remains occur	6	4	1278	4
Shale, black, hard, arenaceous, micaceous; contains plant remains	3		1281	4
Sandstone, banded, shaly		5	1281	9
Shale, dark-colored, arenaceous, with few hard, brown bands, pyritiferous	1	6	1283	3
Shale, light-gray, very fine-grained, arenaceous, in places clayey; contains iron concretions. An inch of coal occurs in the lower part of the bed. Texture somewhat earthy in places	3	8	1286	11

LOG OF DIAMOND DRILL HOLE ON W. F. DAVIS' FARM NEAR FOREST CITY, MISSOURI. DRILLED IN 1901—Continued.

Stratum.	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Pennsylvanian series—Continued.				
Cherokee shale—Continued.				
Sandstone, gray, argillaceous; the lower half is banded by thin partings of shaly carbonaceous material; contains iron concretions	4	9	1291	8
Shale, dark brownish-black, arenaceous; contains ferruginous bands; concretions prominent, pyritiferous, micaceous; grades into argillaceous sandstone at base	10		1301	8
Sandstone, dark-gray, laminated, calcareous, shaly, micaceous	40	4	1342	
Sandstone, shaly, somewhat earthy, containing, especially near the bottom, brown granules of siderite	1	9	1343	9
Shale, dark-gray, sandy; containing numerous brown granules similar to those mentioned above; fossil ferns common	1	7	1345	4
Shale, black, slaty, fine-grained	11	3	1356	7
Sandstone, brownish-black, hard, coarse-grained, containing light bands which effervesce freely, due either to siderite or calcite	1		1357	7
Shale, dark brownish-gray, very arenaceous, micaceous	3	5	1361	
Sandstone, light-gray, rather coarse-grained, micaceous and porous; contains iron concretions	6	4	1367	4
Sandstone, dark-gray, argillaceous, with iron concretions		8	1368	
Sandstone, light-gray, fine-grained, slightly micaceous, argillaceous; contains brownish granules and areas of iron oxide	2	4	1370	4
Sandstone, gray to brownish, banded with thin layers of carbonaceous material; argillaceous	12	9	1383	1
Shale, black, micaceous, with hard brown bands or concretions	1	4	1384	5
Coal		5	1384	10
Clay, gray, sandy at top	2	6	1387	4
Shale, black, carbonaceous, pyritiferous; contains hard, brown bands	2	9	1390	1
Coal		10	1390	11
Clay, gray, soft	1	1	1392	
Wasted core	1	4	1393	4
Clay, gray, grading to black below	1	4	1394	8
Shale, black, carbonaceous, containing a few hard, brown, ferruginous bands	5	5	1400	1
Shale, black, arenaceous, with hard, ferruginous bands; more arenaceous and less laminated at the base	12	6	1412	7
Sandstone, black to brownish-gray, argillaceous, bituminous, calcareous; fossiliferous, especially lower portion	12	9	1425	4

LOG OF DIAMOND DRILL HOLE ON W. F. DAVIS' FARM NEAR FOREST CITY, MISSOURI. DRILLED IN 1901—Continued.

Stratum.	Thickness.		Depth.	
Pennsylvanian series—Continued.	*Ft.*	*in.*	*Ft.*	*in.*
Cherokee shale—Continued.				
Sandstone, gray to light-gray, medium-grained; interbedded with thin carbonaceous layers and containing some bands which are very hard, dense and fine-grained	9	8	1435	
Shale, black, carbonaceous, pyritiferous, containing fossil plants; somewhat calcareous, especially near the top	5		1440	
Clay shale, dark-gray	4		1444	
Sandstone, dark-gray, coarse, argillaceous, brown ferruginous granules abundant	1	8	1445	8
Shale, dark-gray, clayey, slightly arenaceous	8	4	1454	
Sandstone, brown, coarse-grained, argillaceous		3	1454	3
Clay, dark-gray, slightly arenaceous	3	6	1457	9
Sandstone, brown, coarse, argillaceous		7	1458	4
Shale, dark-gray, clayey, slightly arenaceous	5	8	1464	
Shale, arenaceous; similar to that above, but darker	1	9	1465	9
Shale, black, carbonaceous, slaty; slickensided; pyritiferous, especially one foot near middle	14	3	1480	
Shale, black, carbonaceous; shows plant remains and contains numerous hard iron-stained bands; slickensided	4	4	1484	4
Shale like above; calcareous; becomes harder, more sandy and micaceous	4	2	1488	6
Sandstone, light-colored, coarse, hard; contains many slivers of carbonaceous material and large masses of pyrite	1	7	1490	1
Sandstone, light-green to light-buff; banded, fine to medium-grained, micaceous	3	1	1493	2
Shale, dark to light-grayish-blue, clayey; arenaceous at bottom and contains some carbonaceous matter	2	4	1495	6
Sandstone, light-gray to buff; banded, medium-grained. In the upper 6 inches are cavities which were evidently filled with clay. Grades into bed below	2	11	1498	5
Sandstone, striped grayish-blue and buff, argillaceous; streaked and spotted appearance	2	6	1500	11
Sandstone, banded; light-buff separated into thin beds by shale laminae which gives a striped appearance. The shale is more abundant in the middle; micaceous	5	9	1506	8
Shale, black, in part containing slaty, hard, brown bands. The upper portion is banded with thin layers of sandstone but the lower foot is very free from sand	11	6	1518	2
Sandstone, alternating light and dark-banded, dark-colored bands being very micaceous	11	10	1530	

LOG OF DIAMOND DRILL HOLE ON W. F. DAVIS' FARM NEAR FOREST CITY, MISSOURI. DRILLED IN 1901—Continued.

Stratum.	Thickness. Ft.	Thickness. in.	Depth. Ft.	Depth. in.
Pennsylvanian series—Continued.				
Cherokee shale—Continued.				
Coal		2	1530	2
Shale, dark, carbonaceous		4	1530	6
Sandstone, light-gray, fine-grained, argillaceous, fossiliferous	3	8	1534	2
Sandstone, consisting of alternating light and dark-colored bands, the dark bands being argillaceous and becoming more prominent toward base; contains ferruginous concretions; medium to fine-grained	11	7	1545	9
Shale, banded, very arenaceous	6	2	1551	11
Sandstone, bluish-gray, finely-laminated, micaceous; contains much carbonaceous material	3	9	1555	8
Sandstone, buff to yellowish, coarse, pyritiferous; contains numerous plant impressions which show as black streaks	1	7	1557	3
Shale, black, carbonaceous, somewhat sandy in places; contains a one-half inch bed of coal 5 inches from the base	2	10	1560	1
Sandstone, light-colored, very fine-grained, argillaceous, in places carbonaceous; contains Sigillaria and other fossil plants; slickensided	6	2	1566	3
Shale, dark-gray to black, in thin laminae; carbonaceous, with occasional hard, brown, ferruginous bands; slickensided	14		1580	3
Sandstone, fine-grained, argillaceous, calcareous; contains fragments which give it a rough, knotted, conglomeratic appearance	1	11	1582	2
Shale, black, bituminous, slightly micaceous	4	3	1586	5
Sandstone, black, slightly calcareous, argillaceous, fossiliferous, pyritiferous	1	3	1587	8
Shale, black, arenaceous, especially at top, pyritiferous and micaceous	19	4	1607	
Shale, like above except for thin beds of gray, micaceous sandstone in lower 2 feet	6	4	1613	4
Sandstone, light-gray to white, porous; lower 2 feet calcareous, coarse-grained	4	10	1618	2
Limestone, argillaceous, crystalline; contains stylolites with black bituminous material		7	1618	9
Sandstone, like that between 1613-4 and 1618-2, but finer-grained	1	3	1620	
Sandstone, light-gray, calcareous, alternating with irregularly bedded fine-grained gray limestone; stylolites in limestone	1	11	1621	11
Mississippian series:				
St. Louis limestone:				
Limestone, gray to brownish-gray, cherty, semi-crystalline, dense and hard; stylolites which contain black, bituminous material; pyritiferous	11	7	1633	6

LOG OF DIAMOND DRILL HOLE ON W. F. DAVIS' FARM NEAR FOREST CITY, MISSOURI. DRILLED IN 1901—Continued.

Stratum.	Thickness		Depth.	
Mississippian series—Continued.				
St. Louis limestone—Continued.				
Limestone, dark-gray, argillaceous, fine-grained, fossiliferous	2	9	1636	3
Limestone, brownish-gray, dense, fine-grained. Ground-mass with veins and vugs of calcite; stylolites. In lower 2 feet, thin, dark, wavy, shaly bands are abundant and extremely irregular. The two phases grade into each other	7	1	1643	4
Limestone, gray, conglomeratic, separated from above by one-quarter inch shaly band; has some coarse sand grains in cementing material		3	1643	7
Limestone, dark-gray, hard, very fine-grained, having a very dense, compact texture; stylolites are numerous; pyritiferous; contains many small calcite crystals. Eighteen inches from the base is a 2-inch seam of sand and dark shale	11	2	1654	9
Limestone, gray, irregularly bedded, argillaceous and arenaceous, with greenish shaly layers diagonal to core		7	1655	4
Limestone, dark-gray, very fine-grained, compact; has many thin veins of calcite and pyrite; similar to the bed between 1643-7 and 1654-9	5	10	1661	2
Warsaw shale:				
Limestone, dark, pyritiferous, with irregular dark shaly layers		3	1661	5
Shale, yellowish-green		2	1661	7
Limestone, light-gray, fine-grained, slightly arenaceous, earthy near the bottom; grades into arenaceous shale having a greenish color. The latter contains reddish, iron-stained quartz	4	7	1666	2
Dolomite, gray, soft, argillaceous; contains small tubes filled with a white substance, and small white spots	1	6	1667	8
Shale, dark greenish-gray, arenaceous; slightly calcareous; geodes; pyritiferous	4	5	1672	1
Sandstone, blue-green, calcareous, argillaceous; grading to shale at the bottom	1	1	1673	4
Shale, blue-green, arenaceous, micaceous		8	1674	
Shale, gray and green-banded, arenaceous, very fine-grained; contains quartz geodes	3	6	1677	6
Shale, blue, arenaceous		11	1678	5
Sandstone, light, argillaceous, calcareous, fine-grained, texture earthy; resembles a cotton rock; contains a few fossils	1	7	1680	
Limestone, light-gray, in places with darker bands, arenaceous, argillaceous, resembling a cotton rock, texture earthy; con-				

LOG OF DIAMOND DRILL HOLE ON W. F. DAVIS' FARM NEAR FOREST CITY, MISSOURI. DRILLED IN 1901.—Continued.

Stratum.	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Mississippian series—Continued.				
Warsaw shale—Continued.				
tains quartz-lined geodes. Two thin seams of soft dark shale, 2 inches and 4 inches thick, respectively, occur 4 inches apart near middle of bed	10	11	1690	11
Shale, dark greenish-gray; calcareous at top and bottom	1	9	1693	8
Limestone, fine-grained, very arenaceous, cherty, pyritiferous	5	4	1698	
Wasted core	2		1700	
Sandstone, very fine-grained, argillaceous, calcareous; resembles cotton rock	1	6	1701	6
Burlington and Keokuk limestones:				
Limestone, light to dark-gray, shading in places to bluish and brownish-gray; crystalline, coarse to fine-grained; cherty, the chert usually of light color and fossiliferous; stylolites common, and usually showing a thin film of bituminous material; contains five dark shale beds up to 19 inches thick and many thin, dark, shaly partings; fossiliferous	45	3	1746	9
Limestone, coarsely crystalline, showing a peculiar white silicious matrix in which are embedded large and small brownish calcite crystals		7	1747	4
Limestone, similar to that between 1701-6 and 1746-9	12	8	1760	
Limestone, light-gray, medium to very coarsely crystalline, fossiliferous, including large crinoid stems; stylolites prominent. A few dark, thin shale partings; 2 ½ inches of finely laminated soft dark shale 1 foot from top. Chert occurs at intervals and in places is partly decomposed	33	4	1793	4
Limestone, light-gray, fine-grained, arenaceous, argillaceous; porous, especially near middle and toward the bottom. Fossiliferous. Contains chert, some of which is decomposed; stylolites abundant in upper part	6	8	1800	
Limestone, light buff-gray to gray, dense to coarsely crystalline; contains thin shale laminae in places; toward bottom becomes porous, arenaceous dolomitic, cherty, fossiliferous	10	1	1810	1
Limestone, light buff-gray, fine-grained, arenaceous	3	7	1813	8
Wasted core	7	5	1821	1

LOG OF DIAMOND DRILL HOLE ON W. F. DAVIS' FARM NEAR FOREST CITY, MISSOURI. DRILLED IN 1901—Continued.

Stratum.	Thickness.		Depth.	
Mississippian series—Continued.				
Kinderhook group[a]:				
Dolomite or dolomitic limestone; light-gray, porous, earthy, argillaceous, fossiliferous. Thin bands of chert which are usually fossiliferous. Few thin bands of dark-gray to almost black shale. Contains occasional large crystals of calcite one-half to three-quarter inch in diameter, and a few veins of pyrite	15	8	1836	9
Dolomite, gray, crystalline, fine-grained		4	1837	1
Chert, light and dark-gray, containing vugs, knife-blade seams and isolated crystals of calcite	1	9	1838	10
Limestone, gray, coarsely crystalline; very fossiliferous, especially along the bedding planes; bedding planes are very irregular; stylolites	1	2	1840	
Limestone, bluish-gray, coarsely crystalline; very fossiliferous; stylolites whose surface is coated with black and green shaly material	5	9	1845	9
Limestone, light-gray, rather earthy, having the appearance of decomposed chert; fossiliferous; lower part chiefly decomposed chert	2	11	1848	8
Limestone, dark-gray, hard, dense, fossiliferous, alternating with a light-gray, almost white, porous, fossiliferous rock, resembling decomposed chert. The white rock is 3 feet 8 inches thick. Near top of bed contains black partings and some calcite. Chert. Very thin dark shale bands occur in the limestone	29	8	1878	4
Limestone, light to dark-gray, fine-grained, compact, in places with shaly partings; fossiliferous	6	2	1883	4
Limestone, light brownish-gray, hard, dense, fossiliferous, mostly very fine-grained; contains a few irregular carbonaceous shale seams and large masses of secondary calcite crystals	3	10	1887	2
Limestone; the upper 1 foot 5 inches is coarse-grained, containing streaks of dark-brown shale, giving the rock a banded appearance. The next 1 foot and 6 inches is much more shaly and has a darker color, also a striped appearance. The next 9 inches is fine-grained, resembling cotton rock. The remainder of the bed is chiefly coarsely crystalline, light-gray, and has a slightly streaked appearance due to varying amounts of dark shale and bituminous				

[a]May include other beds below 1800 feet.

LOG OF DIAMOND DRILL HOLE ON W. F. DAVIS' FARM NEAR FOREST CITY, MISSOURI. DRILLED IN 1901—Continued.

Stratum.	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Mississippian series—Continued.				
Kinderhook group—Continued.				
matter. Fossiliferous. Shale becomes more prominent toward the base, the bed passing to a shaly limestone, then to a calcareous shale, and grades into the shale below. Shaly portion of bed contains thin black markings of organic origin	26	9	1913	11
Shale, dark-blue, calcareous at top; fossiliferous and pyritiferous; contains black markings like above, also large brownish markings	6	1	1920	
Shale, blue-gray, calcareous, fine-grained, sandy, pyritiferous; the amount of sand increases toward the base; fossiliferous	3	9	1923	9
Shale, dark-gray to sandy with a granular öolitic texture; slightly calcareous		1	1923	10
Shale, blue-green, slightly arenaceous; numerous narrow black impressions at partings which are probably fossil plants; grades into shale below	8	4	1932	2
Shale, purple, texture uniform throughout; in the lower part occur a few thin, dark-brown, bituminous, oölitic streaks less than an inch in thickness	21	3	1953	5
Hematite, dark-red, flat oölites resembling typical "flaxseed" iron ore	3	8	1957	1
Hematite, dark-red, harder than above; not oölitic, fossiliferous		5	1957	6
Shale, bright-green, slightly arenaceous	2	6	1960	
Shale, bluish-gray; pyritiferous. A thin darker clay band at 1973, gradually becomes more calcareous toward base, and contains a number of bands of hard, blue, fine-grained, argillaceous limestone, ranging from 1 inch to 1 foot in thickness; lower 6 feet less calcareous	64	9	2024	9
Shale, gray, calcareous, with earthy texture; very fossiliferous		6	2025	3
Shale, bluish-gray, calcareous; becomes a dark-gray and arenaceous at the base	15	10	2041	1
Devonian (?)[a]:				
Limestone, dark-gray and brown, conglomeratic, hard, dense, mottled. At the top is 1 inch of conglomerate composed of rounded to angular fragments of limestone, but slightly lighter than bed on which it rests. Fragments embedded in shale like above. The lower portion consists of dark-gray fragments embedded in a brown earthy limestone matrix. The fragments contain quartz-lined cavities, probably corals	2	10	2043	11

[a] Correlations below 2041-1 by E. O. Ulrich.

LOG OF DIAMOND DRILL HOLE ON W. F. DAVIS' FARM NEAR FOREST CITY, MISSOURI. DRILLED IN 1901—Continued.

Stratum.	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Devonian (?)—Continued.				
Limestone, dolomitic or dolomite, dark brownish-gray, containing small cavities, uniformly distributed; pyritiferous......	1	8	2045	7
Limestone, light brownish-gray, fine-grained, having an earthy texture resembling a cotton rock..........................	1	6	2047	1
Limestone, gray, medium-grained, semi-crystalline, porous, dolomitic?..........		4	2047	5
Limestone, light and dark-gray, mainly hard and dense, with porous semi-crystalline layers alternating with beds of a light brownish colored limestone having a cotton rock-like texture.................	4	11	2052	4
Limestone, having a conglomeratic aspect; resembles closely bed between 2041-1 and 2043-11............................	4	5	2056	9
Shale, dark bluish-gray, calcareous, having a spotted conglomeratic appearance at the top and the bottom; texture earthy; very fossiliferous at the top and bottom; pyritiferous...............................	5	11	2062	8
Upper Devonian:				
Limestone, dark-gray, very fossiliferous, texture earthy as a rule; shale partings...	17	4	2080	
Limestone, brownish-gray, fine-grained, fossiliferous; bituminous along the wavy shaly partings. Very hard and dense in places. Texture in some parts resembles that of cotton rock. A two and one-half inch band of shale occurs at 2083-8........	5	11	2085	11
Limestone, light-gray, in part crystalline; medium-grained......................	2	6	2088	5
Limestone, dark-gray, chiefly compact, hard, dense, partly crystalline; somewhat of a lithographic texture; bedding irregular. Stylolites abundant in some places. Clay partings give the stone a striped appearance, especially near the top............	7	9	2096	2
Limestone, white, earthy, semi-crystalline; much softer and more porous than the last	1	10	2098	
Limestone, hard, dense, semi-crystalline, with wavy shale partings; has somewhat the texture and appearance of lithographic stone...............................	2		2100	
Limestone, light-gray to bluish-gray, showing wavy shale partings in places. Lower and upper portions are hardest and most compact and have a bluish-gray color. A small portion of the bed has a dull gray color and an earthy texture.................	8	3	2108	3
Limestone, light brownish-gray, hard, dense, containing thin, wavy, black, bituminous,				

LOG OF DIAMOND DRILL HOLE ON W. F. DAVIS' FARM NEAR FOREST CITY, MISSOURI. DRILLED IN 1901.—Continued.

Stratum.	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Devonian—Continued.				
Upper Devonian—Continued.				
shaly partings, giving the rock a banded appearance	1	7	2109	10
Limestone, light to bluish-gray and brownish, hard, dense, semi-crystalline, with several thin dark-greenish shale bands	10	2	2120	
Limestone, light to dark-gray; semi-crystalline to hard and dense. Some stylolites with green and dark shaly material; wavy, shaly partings	14	6	2134	6
Middle Devonian:				
Dolomite, porous and crystalline, between 2134-6 and 2136-6 and 2143 and 2145-4; separating dolomite is limestone similar to above	11	8	2146	2
Dolomite, gray, finely crystalline and dense to earthy, with beds near top and middle very porous	13	10	2160	
Dolomite, very dark gray, finely crystalline, porous in places; contains large vugs of calcite	5	4	2165	4
Dolomite, dark-gray, calcareous, dense; has shaly bituminous partings	2	10	2168	2
Dolomite, somewhat calcareous; cavernous near the base but dense and compact at the top	1	4	2169	6
Limestone, light to dark-gray, brownish in places; slightly magnesian, compact, dense; contains three bands of green calcareous shale	10	8	2180	4
Dolomite, dark-gray to greenish-gray, finely crystalline; porous and cavernous at several different horizons. At the top of the section the color is almost brown. Contains several shale bands	27		2207	4
Dolomite, light-brown, chocolate and bluish-gray, hard. Porous and cavernous in places. Some cavities are one and one-half inches in diameter and lined with dolomite and calcite crystals, the former predominating. Has a finely-crystalline texture. In many places around the cavities the rock has a yellowish or buff-colored appearance indicative of weathering	20	4	2227	8
Dolomite, light bluish-gray, very porous, finely crystalline; contains calcite and dolomite crystals	2	4	2230	
Dolomite, light bluish-gray, with a finely crystalline texture, somewhat porous at top	1	8	2231	8
Dolomite, gray, cherty		11	2232	7
Chert, partly decomposed and chalky in appearance	1	8	2234	3

LOG OF DIAMOND DRILL HOLE ON W. F. DAVIS' FARM NEAR FOREST CITY, MISSOURI. DRILLED IN 1901.—Continued.

Stratum.	Thickness.		Depth.	
	Ft.	in.	Ft.	in.
Devonian—Continued.				
Middle Devonian—Continued.				
Dolomite, brownish, medium-grained, thoroughly crystalline, very porous, cavities up to one and one-half inches in diameter, which are lined with crystals of dark-colored dolomite. One foot is almost all secondary dolomite, there being one 4-inch streak of solid dolomite. The bedding planes are very irregular and rough and frequently coated with a thin film of bituminous or carbonaceous matter. The lower part of the bed contains finer pores and has a light-buff color..........	22	6	2256	9
Dolomite, gray, finely crystalline, compact and hard, slightly porous at the base.....	1	7	2258	4
Dolomite, light-brown, very fine-grained, argillaceous; contains an occasional shaly parting plane. Has a typical cotton rock appearance throughout. Has a large cavity containing dolomite crystals at 2269..............................	34	5	2292	9
Dolomite, brownish-gray, dark, resembling in texture the cotton rock described above	1	9	2294	6
Dolomite, dark, finely crystalline, increasing in porosity toward bottom; cavities become more numerous, fossiliferous.......	4	4	2298	10
Dolomite, in part having the appearance of cotton rock and in part crystalline; more or less porous throughout. Wavy, shaly parting planes. Stylolites. Six feet seven inches from the top is layer one and one-half feet thick of white, dense, hard dolomite, resembling quartzite; dissolves slowly in acid. The cavities in this bed are frequently lined with dolomite crystals. This white, dense, crystalline dolomite also occurs in less quantity at other levels in this bed; cherty in places...	21	2	2320	
Dolomite, light-gray to whitish; resembles cotton rock, cherty at middle............	12	3	2332	3
Dolomite, gray, hard, dense, alternating with thin plates of shale; becomes harder toward the base and at bottom is somewhat porous........................	3	2	2335	5
Dolomite, very dark, grayish-brown, medium-grained, crystalline, cavernous, the cavities being lined with dolomite crystals. The upper one and one-half feet have a conglomeratic appearance.................	7	6	2342	11
Dolomite, light brownish-gray, fine-grained, crystalline; contains cavities at top and bottom, compact and hard.............	5	2	2348	1

LOG OF DIAMOND DRILL HOLE ON W. F. DAVIS' FARM NEAR FOREST CITY, MISSOURI. DRILLED IN 1901.—Continued.

Stratum.	Thickness. Ft.	Thickness. in.	Depth. Ft.	Depth. in.
Devonian—Continued.				
Middle Devonian—Continued				
Dolomite, light brownish-gray, very cavernous, crystalline; cavities lined with dolomite crystals	1		2349	1
Dolomite, light brownish-gray, fine-grained, compact; thinly laminated and shaly at base where it breaks into thin plates. Partings dark and bituminous. Chert at top	4	1	2353	2
Dolomite, light-brown, fine-grained, crystalline; very finely porous throughout and contains occasional larger cavities irregularly distributed	4	2	2357	4
Dolomite, light grayish-brown; very hackly and porous, especially at base. Siliceous at base. The cavities are lined with small quartz crystals	1	4	2358	8
Dolomite, light grayish-brown, dense, compact, finely-crystalline	2	10	2361	6
Dolomite, very porous, siliceous		9	2362	3
Dolomite, light brownish-gray, fine-grained; contains quartz druses	2	2	2364	5
Dolomite, bluish-gray; contains quartz lined cavities and irregular masses of chert		8	2365	1
Silurian (Lockport group of Niagaran series):				
Dolomite, bluish-gray, crystalline, contains numerous cavities uniformly distributed throughout. The crystals lining the cavities are chiefly dolomite, although some are calcite. Very fossiliferous; casts of crinoid stems abundant	34	11	2400	
Wasted core		6	2400	6
Dolomite, bluish-gray to brownish; very porous and cavernous. Thoroughly crystalline. Fossiliferous, casts of crinoid stems being very prominent. Large masses of calcite crystals at several levels. One bed contains thin bands of green shale. There are also thin bands of hard, dense dolomite, but very slightly porous, increasing toward bottom	35	8	2436	2
Dolomite, dark-gray, more dense and compact than above, crystalline, less fossiliferous	3	10	2440	
Dolomite, bluish-gray, hard, finely-crystalline. Porous throughout, becoming less so, however, near the base. Cavities an inch to an inch and one-half in diameter occur at intervals	11	6	2451	6
Dolomite, bluish-gray, finely crystalline; similar to the above but denser and harder; contains stylolites and a little shale along the parting planes. Fossiliferous	3	6	2455	

LOG OF DIAMOND DRILL HOLE ON W. F. DAVIS' FARM NEAR FOREST CITY, MISSOURI. DRILLED IN 1901.—Continued.

Stratum.	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Silurian (Lockport group of Niagarian series)—Continued.				
Dolomite, shaly, having a conglomeratic appearance	1		2456	
Dolomite, bluish-gray, hard, dense; stylolites; very few cavities	2		2458	
Dolomite, bluish-gray, finely crystalline, containing numerous small scattered cavities; stylolites occur throughout, fossiliferous: two feet four inches from the top there is a four-inch layer of hard, dense compact dolomite	7	7	2465	7
Dolomite, similar to the above but less porous, except toward the base, where the cavities are practically as numerous	7	4	2472	11
Dolomite, argillaceous. Very irregularly bedded; has a conglomeratic appearance, due to angular chert fragments. Contains several thin irregular layers of black pyritiferous, carbonaceous shale	5	9	2478	8
Dolomite, light bluish-gray, hard, dense	2		2480	8
Dolomite, light-gray, compact; somewhat argillaceous, banded with a few horizontal shaly partings from the eighth to the twelfth foot. Slightly speckled at about the thirteenth foot. Contains but few cavities. Fossiliferous. Resembles cotton rock. The bedding planes are frequently discolored with bituminous shaly matter	18	4	2499	
Dolomite, brown, hard, somewhat porous; some fossils	1		2500	

RECORD OF STRATA IN CORE DRILLING AT MARYVILLE.[1]

(Altitude of surface at curb, 1051 feet.)

	Thickness		Depth	
Pleistocene series:	*Ft.*	*in.*	*Ft.*	*in.*
Clay, sand, and a little gravel	50		50	
Soft shale (probably glacial clay)	120		170	
Pennsylvanian series:				
Shawnee formation:				
Tecumseh shale:				
Shale, dark, argillaceous, growing calcareous at bottom	1		171	
Shale, drab, highly calcareous, compact like limestone	5		176	
Lecompton limestone:				
Limestone, argillaceous, somewhat granular	10		186	
Limestone, dark, coarse, hard, with shell fragments, argillaceous	4		190	

[1]Drilled in the year 1888, 1½ blocks north of Burlington depot (NE. ¼ SE. ¼ sec. 17, T. 64 N., R. 35 W.) Core examined and tested with acid by Arthur Winslow and record made by him.

RECORD OF STRATA IN CORE DRILLING AT MARYVILLE—Continued.

Stratum.	Thickness.		Depth.	
	Ft.	in.	Ft.	in.
Pennsylvanian series—Continued.				
Shawnee formation—Continued.				
Kanwaka shale:				
Shale, black, slightly calcareous, grading into limestone at bottom	3		193	
Shale, calcareous, fine-grained, grading into dark shale toward bottom	4		197	
Limestone, dark, drab, coarse, somewhat granular, with fragments	2		199	
Limestone, white, compact, hard, clinking	4		203	
Shale, dark, somewhat sandy, micaceous, not calcareous, grading into next above	6		209	
Shale, dark, very fine and smooth-grained, argillaceous, growing calcareous towards bottom	7		216	
Douglas formation:				
Oread limestone:				
Limestone, dark, earthy, and coarse, with shell fragments	2		218	
Shale, dark, smooth, non-calcareous	5	6	223	6
Limestone, white, coarse, hard, with dark streaks and shell fragments	10	6	234	
Shale, dark, argillaceous		3	234	3
Limestone, white, coarse, with frequent dark streaks like second above, semi-crystalline and fossiliferous	10	9	245	
Shale, dark, argillaceous, non-calcareous	4		249	
Shale, drab, somewhat arenaceous, slightly calcareous	1		250	
Shale, dark, argillaceous, slightly calcareous	2		252	
Limestone, drab, shaly, grading into calcareous shale	3		255	
Lawrence shale:				
Shale, drab, soft, clayey, calcareous	9		264	
Shale, red, concretionary, calcareous and argillaceous, with drab bands	12		276	
Shale, drab, argillaceous, and calcareous	1		277	
Limestone, drab and dark, with flint, very hard, with calcite crystals	1		278	
Clay, dark red, argillaceous and calcareous, solid red upper 4 feet, lower 2-3 streaked with drab clay shale, the latter preponderating near bottom	12		290	
Shale, arenaceous, slightly calcareous, with fine mica scales, pyritiferous	5		295	
Sandstone, coarse, rough, micaceous, and calcareous	2		297	
Shale, dark drab, argillaceous, non-calcareous, bituminous near the bottom	9		306	
Coal		3	306	3
Shale, drab, argillaceous	4	9	311	
Shale, red, clayey, too soft for core (no specimen)	4		315	
Shale, drab, argillaceous (no specimen)	8		323	
Shale, drab, somewhat arenaceous, argillaceous, non-calcareous, slightly micaceous	27		350	

RECORD OF STRATA IN CORE DRILLING AT MARYVILLE—Continued.

Stratum.	Thickness.	Depth.
Pennsylvanian series—Continued.	*Ft. in.*	*Ft. in.*
Douglas formation—Continued.		
Lawrence shale—Continued.		
Sandstone, or sandy shale, drab, micaceous and non-calcareous with argillaceous portions	11	361
Shale, drab, arenaceous and argillaceous, with mica, non-calcareous, arenaceous like above in places	22	833
Shale, drab, argillaceous, non-calcareous	7	390
Shale, drab, calcareous, rough and concretionary in places, gritty and greenish near bottom, with pyrites	13	403
Shale, red, argillaceous, non-calcareous	2	405
Shale, drab, argillaceous, non-calcareous, fine mica	7	412
Iatan(?) limestone:		
Limestone, gray, hard, fossiliferous, semi-crystalline	4	416
Weston(?) shale:		
Shale, drab, argillaceous, non-calcareous, black shale at bottom, with some indications of coal	38	454
Lansing formation:		
Stanton-Plattsburg limestone:		
Limestone, dark drab, compact and rough, earthy	4	458
Shale, drab, calcareous, argillaceous	3	461
Limestone, white, very hard, compact, clinking	3	464
Limestone, drab, compact, more earthy	9	473
Limestone, drab, very hard, fossiliferous, semi-crystalline	2	475
Shale, drab, argillaceous, and calcareous (no specimen)	4	479
Shale, black, bituminous, calcareous	2	481
Shale, gray, calcareous, rough	1	482
Limestone, dark, flinty, hard	5	487
Shale, dark gray, sandy, calcareous	1	488
Limestone, gray, coarse, shaly	2	490
Shale, dark gray, argillaceous, non-calcareous, passing into calcareous shale at bottom	1	491
Limestone, white and gray with a little white chert, hard, compact	12	503
Lane shale:		
Shale, light and dark drab, argillaceous, and calcareous, fossiliferous	10	513
Limestone, gray, compact, hard, shaly, passing into shale	2	515
Shale, dark drab, argillaceous and calcareous	10	525
Limestone, nodular, with shale	10	535
Limestone, white, compact, earthy (with next above probably Farley limestone bed)	7	542

RECORD OF STRATA IN CORE DRILLING AT MARYVILLE—Continued

Stratum.	Thickness.	Depth.
	Ft. in.	*Ft. in.*
Pennsylvanian series—Continued.		
Lanting formation—Continued		
Lane shale—Continued		
Shale, light drab and dark gray, argillaceous, calcareous, passing into shaly limestone in the last two feet	25	567
Kansas City formation:		
Iola limestone and Chanute shale:		
Limestone, drab, hard, coarse-grained, semi-crystalline	10	577
Shale, drab, argillaceous, and calcareous	5	582
Shale, black, bituminous and calcareous	2	584
Shale, drab, argillaceous, calcareous, rough in places	9	593
Shale, light gray, calcareous, more of a limestone, seamy	5	598
Limestone, light gray or white, compact	4	602
Shale, light drab, argillaceous, calcareous	6	608
Limestone, light drab, hard, compact	3	611
Limestone and drab shale, more shale at bottom	3	614
Shale, dark, bituminous, calcareous	2	616
Drum limestone:		
Limestone, dark, hard, semi-crystalline	4	620
Cherryvale shale:		
Shale, dark, argillaceous, calcareous	10	630
Shale, dark, argillaceous, calcareous, streaked with seams of limestone	10	640
Limestone, dark, granular	3	643
Shale, dark, hard, calcareous, argillaceous near bottom	8	651
Winterset limestone:		
Limestone, white, compact, and crystalline	8	659
Limestone, drab, more compact than last and very hard	20	679
Galesburg shale:		
Shale, black, bituminous, calcareous	4	683
Shale, dark drab, non-calcareous	2	685
Shale, light gray, slightly calcareous	8	693
Bethany Falls limestone:		
Limestone, gray, compact, very hard	19	712
Ladore shale:		
Shale, black, bituminous, slightly calcareous	1	713
Limestone, drab, compact, shaly, argillaceous in lower part	4	717
Shale, clayey, slacks readily, slightly calcareous	5	722
Hertha limestone:		
Limestone, white, gray, very hard, compact	6	728
Pleasanton formation:		
Limestone, reddish, sandy, friable spots	2	730
Shale, dark, argillaceous, barely calcareous	1	731
Limestone, reddish, sandy and ferruginous like second above	6	737

RECORD OF STRATA IN CORE DRILLING AT MARYVILLE—Continued

Stratum.	Thickness.	Depth.
	Ft. in.	*Ft. in.*
Pennsylvanian series—Continued.		
Pleasanton formation—Continued.		
Limestone, drab, compact, granular.......	3	740
Shale, black, bituminous..................	2	742
Limestone, nodular, some shale, slightly pyritiferous..................	11	753
Shale, arenaceous, a little mica, non-calcareous..................	14	767
Limestone, drab, compact, smooth, somewhat earthy..................	7	774
Shale, drab, slightly argillaceous, arenaceous, fine mica, non-calcareous..............	6	780
Limestone, white, hard, semi-crystalline...	4	784
Shale, dark, argillaceous, slightly calcareous..	2	786
Shale, drab and greenish, argillaceous, calcareous in places and occasional limestone streaks..................	13	799
Limestone, white, and ferruginous from pyrites, hard..................	1	800
Limestone, shaly and brecciated..........	3	803
Shale, greenish, argillaceous, non-calcareous.	6	809
Limestone, drab, hard, compact, granular...	1	810
Shale, greenish drab, argillaceous, non-calcareous..................	10	820
Shale, reddish, mottled, argillaceous........	7 (?)	827 (?)
Shale, drab, argillaceous, slightly calcareous and micaceous near bottom............	9 (?)	836
Shale, drab, argillaceous, somewhat arenaceous near top, non-calcareous, micaceous; lower portion drab, calcareous, strongly effervescent..................	10	846
Henrietta formation:[1]		
Limestone, granular, somewhat argillaceous.	5	851
Shale, drab, somewhat arenaceous, micaceous..................	11	862
Shale, argillaceous, growing dark towards bottom..................	13	875
Limestone, coarse, granular toward bottom	4	879
Shale, dark, argillaceous, and very effervescent, granular calcareous streaks in places..................	15	894
Limestone, drab, argillaceous, fine-grained, compact..................	6	900
Limestone, drab, coarse-grained, not crystalline..................	3	903
Limestone, light gray, finer-grained than next above..................	2	905
Cherokee shale:		
Shale, drab, argillaceous, calcareous........	26	931
Shale, drab, arenaceous, micaceous calcareous approaching sandstone in places	12	943

[1]Determination of contact tentative.

RECORD OF STRATA IN CORE DRILLING AT MARYVILLE—Continued.

Stratum.	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Pennsylvanian series—Continued.				
Cherokee shale—Continued.				
Shale, drab, arenaceous, micaceous, non-calcareous	15		958	
Shale, drab, argillaceous, non-calcareous	15		973	
Shale, drab, slightly arenaceous, and calcareous	12		985	
Shale, drab, argillaceous and slightly arenaceous, mostly non-calcareous	18		1003	

RECORD OF STRATA IN CORE DRILLING NEAR RAYTOWN.[1]

Stratum.	Thickness.		Depth.	
Pennsylvanian series:				
Kansas City formation:				
Chanute and Cherryvale shale:				
Shale, light, calcareous	32		32	
Limestone	2		34	
Shale, blue	17	6	51	6
Winterset limestone:				
Limestone	15	3	66	9
Galesburg shale:				
Shale, slaty	3	2	69	11
Bethany Falls limestone:				
Limestone	22	9	92	8
Ladore shale:				
Shale, slaty	4	7	97	3
Hertha limestone:				
Limestone	15		112	3
Pleasanton formation:				
Shale, some parts gritty	94	9	207	
Coal		2	207	2
Shale, some parts gritty	61	3	268	5
Henrietta formation:				
Limestone	8	7	277	
Shale, slaty	11		288	
Limestone	4		292	
Slate		10	292	10
Coal	1	6	294	4
Fire clay, hard	5	8	300	
Limestone	5		305	
Shale, slaty	14	2	319	2
Limestone	4	3	323	5
Cherokee shale:				
Slate	1	1	324	6
Coal (Lexington)	1	2	325	8
Slate (Lexington)		8	326	4
Coal (Lexington)		9	327	1

[1]Ten miles southeast of Kansas City (sec. 7, T. 48 N., R. 32 W.). Drilled in 1886. Record furnished by S. J. Hatch.

RECORD OF STRATA IN CORE DRILLING NEAR RAYTOWN—Continued.

Stratum.	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Pennsylvanian series—Continued.				
Cherokee shale—Continued.				
Limestone	12	9	339	10
Shale	12	2	352	
Limestone, hard ("Rhomboidal")	3	6	355	6
Slate, black	3		358	6
Coal (Summit)	1	3	359	9
Fire clay	2	7	362	4
Limestone	7	1	369	5
Shale	4		373	5
Limestone	4	3	377	8
Slate	3		380	8
Coal (Mulky)	1		381	8
Fire clay	5	8	387	4
Sandstone	11	10	399	2
Sandstone, streaks of slate or shale	32	3	431	5
Shale, slaty	15	4	446	9
Slate and shale	5	6	452	3
Coal (Bevier)	1	8	453	11
Shale and slate	49		502	11
Slate	6		508	11
Coal	1	4	510	3
Limestone	8		518	3
Slate and shale	6		524	3
Coal		10	525	1
Limestone	18	6	543	7
Sandstone, showing of gas	16	2	559	9
Shale, sandy	23	2	582	11
Shale, sandy, micaceous	37	7	620	6
Shale, sandy, streaks of slate	33	2	653	8
Sandstone	15	7	669	3
Shale, sandy	24		693	3
Shale	15		708	3
Sandstone, coarse, salt water	43	9	752	
Mississippian series:				
Burlington-Keokuk:				
Limestone, shelly in places, with shale partings	73		825	
Limestone, light-colored, flinty layers	260		1085	
Kinderhook group (?):				
Limestone, dark, with shelly layers	100		1185	
Sand, dark-reddish	15		1200	
Ordovician:				
Joachim (?)[1]:				
Limestone, bluish, fine-grained, shelly in places	57		1257	
St. Peter:				
Sandstone, white at top, reddish at bottom	64		1321	
Cambro-Ordovician:				
Limestone, gray and brown	129		1450	
Limestone, shelly and clayey	10		1460	

[1]Correlation below 1,200 feet by E. O. Ulrich, U. S. Geol. Survey Water-Supply Paper 195, p. 86, 1907.

RECORD OF STRATA IN CORE DRILLING NEAR RAYTOWN—Continued.

Stratum.	Thickness.	Depth.
	Feet.	*Feet.*
Cambro-Ordovician—Continued.		
Limestone, light, coarse, and porous	160	1620
Limestone, shelly	20	1640
Sandstone, white	16	1656
Limestone, light, flinty, porous, water disappeared or was lost	74	1730
Limestone, gray, clayey, and sandy	20	1750
Limestone, gray, hard, fine-grained	70	1820
Sandstone, gray, hard, fine-grained	15	1835
Limestone, gritty, porous, crystalline, in places white and flinty	215	2050
Sandstone, hard, coarse	50	2100
Cambrian:		
Limestone, with seams of gray and brown shale	40	2140
Limestone, dark and light, fine-grained	110	2250
Sandstone, hard, coarse	98	2348
Proterozoic:		
Granite	53	2401

RECORD OF STRATA IN CORE DRILLING EAST OF MERWIN.

(W. ½ NE. ¼ sec. 27, T. 42 N., R. 32 W.)

Stratum.	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Recent series:				
Soil and gravel	17	5	17	5
Pennsylvanian series:				
Pleasanton formation:				
Sandstone, gray	40	7	58	
Limestone	2	10	60	10
Shale, dark	3		63	10
Limestone	3	10	67	8
Shale, gray	2	8	70	4
Coal (Mulberry)	1	4	71	8
Clay		10	72	6
Shale, gray	4	6	77	
Henrietta formation:				
Pawnee limestone:				
Limestone, hard	11	8	88	8
Labette shale:				
Shale, calcareous	2	6	91	2
Shale, sandy	5		96	2
Shale, gray	3		99	2
Shale, dark	6	5	105	7
Limestone	4	4	109	11
Shale, dark, slaty	5	6	115	5
Sandstone		9	116	2
Shale, sandy	8		124	2
Shale, dark	1	2	125	4
Coal, with partings		2	125	6
Shale, soft	10	5	135	11

RECORD OF STRATA IN CORE DRILLING EAST OF MERWIN—Continued.

Stratum.	Thickness.		Depth.	
Pennsylvanian series—Continued.				
Henrietta formation—Continued.	*Ft.*	*in.*	*Ft.*	*in.*
Fort Scott limestone:				
Limestone, gray	15	7	151	6
Shale, black, slaty	4	8	156	2
Shale, light	10		166	2
Cherokee shale:				
Shale, dark, slaty	4	2	170	4
Coal		2	170	6
Clay	1	6	172	
Sandstone	1	2	173	2
Shale, sandy	14		187	2
Sandstone	69	10	257	
Shale, black, slaty		4	257	4
Limestone	10	1	267	5
Shale, gray		9	268	2
Shale, black, slaty		10	269	
Shale, dark	13	11	282	11
Coal (Mulky?)		9	283	8
Clay	6	6	290	2
Shale, dark	2	4	292	6
Sandstone	3	4	295	10
Shale, gray	6	4	302	2
Shale, light to dark	7	4	309	6
Coal (upper Rich Hill)	2	2	311	8
Clay	2	6	314	2
Shale	1		315	2
Shale, dark to black, slaty	27		342	2
Coal (lower Rich Hill)	2	5	344	7
Clay	1	3	345	10
Shale, dark	5		350	10
Limestone	1	4	352	2
Shale, "slaty"	2		354	2
Limestone and shale	10		364	2
Sandstone, dark to light	9		373	2
Shale, gray, sandy	2	10	376	
Coal, with partings		6	376	6
Shale, dark	9	8	386	2
Shale, sandy	1	8	387	10
Limestone	1	4	389	2
Shale, dark, slaty	17		406	2
Shale, calcareous	2	2	408	4
Shale, sandy	2	3	410	7
Shale, light	8	7	419	2
Shale, sandy	33		452	2
Shale, dark	2	6	454	8
Shale, black, slaty		8	455	4
Coal		5	455	9
Clay, dark	1	5	457	2
Shale, dark	10		467	2
Shale, light, sandy	2		469	2
Shale, gray	7		476	2
Shale, dark	9		485	2
Shale, hard	9		494	2
Shale, calcareous	3		497	2
Mississippian series:				
Limestone	6		503	2

RECORD OF STRATA IN DRILLING NEAR BERLIN.[1]

(Altitude of surface at curb about 870 feet.)

Stratum.	Thickness.	Depth.
	Feet.	*Feet.*
Recent series:		
Soil and gravel	14	14
Pennsylvanian series:		
Lansing formation:		
Plattsburg limestone:		
Limestone, hard	12	26
Shale, light blue	3	29
Limestone, soft	2	31
Lane shale:		
Shale	3	34
Limestone	3	37
Shale	2	39
Limestone	2	41
Shale	4	45
Limestone	2	47
Shale, blue	31	78
Kansas City formation:		
Iola limestone:		
Limestone and sand	2½	80½
Chanute shale:		
Shale	9½	90
Limestone, shelly	1	91
Shale	1	92
Sand	3	95
Slate, black	4	99
Shale, blue	10	109
Shale, light	11	120
Drum limestone (probably includes Cement City limestone bed near base of Chanute shale):		
Limestone, white	6	126
Limestone, gray	12	138
Cherryvale shale:		
Shale, light	15	153
Shale, blue	4	157
Limestone	3	160
Shale	4	164
Winterset limestone:		
Limestone	40	204
Galesburg shale:		
Shale	6	210
Bethany Falls limestone:		
Limestone	20	230
Ladore shale:		
Shale, dark	4	234
Shale, and shelly lime	6	240
Hertha limestone:		
Limestone	10	250

[1]Prospect well for coal, oil, and gas, made with a churn drill in 1913 for the Berlin Coal, Oil, and Gas Prospecting Co., in the NE. ¼ SW. ¼ sec. 22, T. 61 N., R. 31 W.

RECORD OF STRATA IN DRILLING NEAR BERLIN—Continued

Stratum.	Thickness.	Depth.
	Feet.	*Feet.*
Pennsylvanian series—Continued.		
Pleasanton formation:		
Shale, blue	4	254
Shale, light	75	329
Shale, dark	4	333
Shale, light	8	341
Shale, light, sandy	13	354
Shale, white	41	395
Henrietta formation:		
Limestone	2	397
Shale, white	8	405
Shale, blue	12	417
Shale, blue, and slate	15	432
Cherokee shale:		
Shale, black, and coal (Lexington)	6	438
Shale, sandy	5	443
Limestone	6	449
Shale, light	2	451
Shale, dark	14	465
Shale, blue	20	485
Shale, sandy	25	510
Shale, blue, sandy	60	570
Sandstone, red	6	576
Shale, blue, sandy	45	621
Shale, blue	25	646
Sandstone, white	24	670
Shale, sandy	10	680
Sandstone	16	696
Sandstone	7	703
Slate, black	2	705
Shale, white	30	735
Shale, dark	8	743
Limestone	6	749
Shale, sandy	16	765
Limestone	2	767
Shale, sandy	3	770
Limestone	1	771
Shale, sandy	9	780
Shale, light	13	793
Shale, dark	25	818
Shale, white	10	828
Slate	1	829
Coal	2	831
Slate	1	832
Coal	2	834
Sandstone	6	840
Shale	25	865
Limestone	2	867
Shale	16	883
Sandstone, white	56	939
Shale, dark	12	951
Sandstone	2	953
Shale, black, sandy	4	957
Shale, black	64	1021

RECORD OF STRATA IN DRILLING NEAR BERLIN—Continued.

Stratum.	Thickness.	Depth.
	Ft. in.	*Ft. in.*
Pennsylvanian series—Continued.		
Cherokee shale—Continued.		
Shale, sandy	4	1025
Shale, sandy	15	1040
Shale, dark	30	1070
Shale	22	1092*a*
Sandstone	24	1116
Sandstone	16	1132
Mississippian series:		
Limestone	8	1140

*a*Men in charge of the well claim drillers made a mistake between 957 and 1,092, and that total depth should be 1,092 feet.

RECORD OF STRATA IN CORE DRILLING ON KEATING FARM ABOUT THREE MILES SOUTH OF PRINCETON.

(Sec. 8, T. 64 N., R. 24 W.) Drilled in 1914.

Stratum.	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Pleistocene series:				
Surface	8		8	
Pennsylvanian series:				
Kansas City formation:				
Ladore shale:				
Limestone, "bastard"	1		9	
Shale, light, soft	2	6	11	6
Hertha limestone:				
Limestone, white	4	6	16	
Pleasanton formation:				
Shale, green	3		19	
Shale, dark	11	6	30	6
Coal (Ovid)		4	30	10
Shale, light	4	2	35	
Shale, dark	4		39	
Limestone	3		42	
Shale, light	6		48	
Shale, dark, slaty	6		54	
Sandstone, gray, soft	82		136	
Shale, green	17		153	
Henrietta formation:				
Limestone, white	1		154	
Shale, red	8		162	
Shale, calcareous	6		168	
Shale, variegated	10		178	
Cherokee shale:				
Shale, black	6		184	
Coal (Lexington)		6	184	6
Shale (Lexington)		6	185	
Coal (Lexington)	1	8	186	8

RECORD OF STRATA IN CORE DRILLING ON KEATING FARM ABOUT THREE MILES SOUTH OF PRINCETON—Continued.

Stratum.	Thickness.		Depth.	
	Ft.	in.	Ft.	in.
Pennsylvanian series—Continued.				
Cherokee shale—Continued.				
Fire clay	3		189	8
Limestone	6	4	196	
Sandstone	16		212	
Shale, sandy, slaty	7		219	
Coal (Summit)		9	219	9
Limestone, hard	6	3	226	
Shale, calcareous	5		231	
Coal (Mulky)		4	231	4
Fire clay	3	6	234	10
Shale, light	5		239	10
Sandstone, soft, gray	55	2	295	
Coal (upper bench of Bevier)		5	295	5
Fire clay	4	7	300	
Shale, sandy	10		310	
Shale, dark, slaty	9		319	
Coal (lower bench of Bevier)	1	4	320	4
Fire clay	3	8	324	
Shale, light	9		333	
Clay, black	2		335	
Coal (Lower Ardmore)		10	335	10
Fire clay	2	2	338	
Sandstone	10	6	348	6
Shale, light	3	6	352	
Shale, sandy	2		354	
Shale, with fire clay	1		355	
Shale, calcareous	4		359	
Shale, black, slaty	3		362	
Coal		10	362	10
Fire clay	1	2	364	
Shale, dark, slaty	6		370	
Coal	1	6	371	6
Shale, light	2	6	374	
Shale, dark, hard, slaty	76		450	
Shale, slaty, sandy	6		456	
Shale, black, slaty	4	6	460	6
Sandstone, fossiliferous	7	6	468	
Shale, slaty, sandy	1		469	
Shale, dark, slaty	3		472	
Sandstone, gray	6		478	
Fire clay, sandy	4		482	
Shale, black, slaty		4	482	4
Sandstone, gray	3	6	485	10
Shale, black, slaty	4	8	490	6
Coal		9	491	3
Fire clay	3	5	494	8
Shale, slaty, sandy	3	4	498	
Clay, black	2	2	500	2
Coal	1	2	501	4
Fire clay, sandy	1	2	502	6
Sandstone, gray	3	6	506	
Shale, black, slaty	6	6	512	6

RECORD OF STRATA IN CORE DRILLING ON KEATING FARM ABOUT THREE MILES SOUTH OF PRINCETON—Continued.

Stratum.	Thickness. Ft.	Thickness. in.	Depth. Ft.	Depth. in.
Pennsylvanian series—Continued.				
Cherokee shale—Continued.				
Fire clay	2		514	6
Sandstone	3	6	518	
Shale, black, slaty		11	518	11
Coal (Cainesville)	2	6	521	5
"Binder" (Cainesville)	2	2	523	7
Coal (Cainesville)	2	7	526	2
Fire clay	1	10	528	
Shale, light	2		530	

RECORD OF STRATA IN CORE DRILLING NEAR SAXTON.[1]

Stratum.	Thickness. Ft.	Thickness. in.	Depth. Ft.	Depth. in.
Pleistocene series:				
Clay	23		23	
Sand	2		25	
Gravel	4		29	
Pennsylvanian series:				
Douglas formation:				
Weston shale:				
Shale, blue	1		30	
Lansing formation:				
Stanton limestone:				
Limestone	1		31	
Shale, blue	1		32	
Limestone	20		52	
Vilas shale:				
Shale, blue	4	6	56	6
Plattsburg limestone:				
Limestone	16	6	73	
Lane shale:				
Shale, blue	6		79	
Limestone	1		80	
Sandstone	17		97	
Shale, blue	1		98	
Limestone	2		100	
Shale, blue	9		109	
Limestone	4		113	
Shale, blue	4		117	
Limestone	1		118	
Shale, blue	38		156	
Kansas City formation:				
Iola limestone and Chanute shale:				
Limestone	7	6	163	6
Limestone, fossiliferous	4		167	6

[1]Drilled between May 3 and June 26, 1900. Reported to be near junction of Platte and 102 rivers.

RECORD OF STRATA IN CORE DRILLING NEAR SAXTON—Continued.

Stratum.	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Pennsylvanian series—Continued.				
Kansas City formation—Continued.				
Iola limestone and Chanute shale—Continued.				
Shale, blue	3	6	171	
Shale, black	1	6	172	6
Limestone		6	173	
Shale, blue	5		178	
Shale, gray	4		182	
Limestone	4		186	
Shale, blue	8		194	
Drum limestone[1]:				
Limestone	6		200	
Cherryvale shale:				
Shale, blue	1	6	201	6
Limestone	1		202	6
Shale, blue	3	6	206	
Limestone	5		211	
Shale, blue	7		218	
Shale, fossiliferous	4		222	
Shale, blue	2		224	
Limestone	2		226	
Shale, blue	7		233	
Limestone	5		238	
Shale, blue	6		244	
Winterset limestone:				
Limestone	8		252	
Shale, blue	1		253	
Limestone	20		273	
Galesburg shale:				
Shale, blue	2		275	
Shale, black	2		277	
Shale, blue	2		279	
Bethany Falls limestone:				
Limestone	21	6	300	6
Ladore shale:				
Shale, blue	2		302	6
Hertha limestone:				
Limestone	18	6	321	
Pleasanton formation:				
Shale, black	1		322	
Coal (Ovid)		1	322	1
Shale, blue		11	323	
Shale, sandy	40		363	
Shale, blue	45		408	
Shale, clayey	3		411	
Shale, blue	5		416	
Shale, sandy	13		429	
Shale, blue	11		440	
Limestone	1		441	
Shale, blue	8		449	
Henrietta formation:				
Limestone	3		452	
Shale, sandy	6		458	

[1]May include some of the thin beds below.

RECORD OF STRATA IN CORE DRILLING NEAR SAXTON—Continued.

Stratum.	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Pennsylvanian series—Continued.				
Henrietta formation—Continued.				
Limestone	2		460	
Shale, sandy	3		463	
Shale, blue	12		475	
Shale, calcareous	8		483	
Limestone, conglomeratic	2		485	
Shale, black	3		488	
Limestone	1		489	
Sandstone	6		495	
Shale, black	11	6	506	6
Limestone, blue	1	6	508	
Shale, blue	1		509	
Shale, black	1		510	
Shale, blue		5	510	5
Coal		7	511	
Shale, blue	8		519	
Limestone	7		526	
Shale, blue	9		535	
Limestone	3		538	
Shale, mixed with limestone	5		543	
Limestone	4	6	547	6
Cherokee shale:				
Shale, with layers of sand	3		550	6
Shale, blue	2	6	553	
Sandstone	5		558	
Shale, clayey	4		562	
Sandstone	3		565	
Shale, sandy	13		578	
Shale, blue	9		587	
Sandstone	3		590	
Shale, blue	6		596	
Sandstone	2		598	
Shale, blue	16		614	
"Cap rock"	1		615	
Coal (Bedford)	1	8	616	8
Sandstone	11	4	628	
Shale, blue	17		645	
Coal (Bevier)	1	9	646	9
Shale, blue	3	3	650	
Limestone	3		653	
Shale, blue	4		657	
Shale, sandy	8		665	
Shale, blue	2		667	
Sandstone	8		675	
Shale, sandy	5		680	
Shale, black	3		683	
Shale, sandy	3		686	
Shale, black	2	4	688	4
Coal	1	5	689	9
Shale, blue	2	3	692	
Shale, sandy	18		710	
Shale, black	8	6	718	6
Coal	1	6	720	

RECORD OF STRATA IN CORE DRILLING NEAR SAXTON—Continued.

Stratum.	Thickness.		Depth.	
	Ft.	in.	Ft.	in.
Pennsylvanian series—Continued.				
Cherokee shale—Continued.				
Shale, clayey	14		734	
Shale, black	8	9	742	9
Coal	1	6	744	3
Shale, blue	3	9	748	
Shale, sandy	9		757	
Coal, slaty		3	757	3
Shale, sandy	9	9	767	
Shale, blue	2		769	
Sandstone	11		780	
Shale, blue	4		784	
Sandstone	2		786	
Shale, blue	80		866	
Sandstone	1		867	
Shale, blue	3		870	
Sandstone	12		882	
Conglomerate	5		887	
Shale, sandy	17		904	
Shale, blue	5		909	
Sandstone	9		918	
Shale, sandy	1		919	
Sandstone	9		928	
Coal		6	928	6
Shale, blue	20	6	949	
Coal		7	949	7
Shale, sandy	6	5	956	
Shale, blue	4	4	960	4
Coal	1	4	961	8
Sandstone	3	4	965	
Shale, blue	7		972	
Limestone	3		975	
Shale, blue	7		982	
Sandstone	2		984	
Shale, blue	6		990	
Shale, sandy	3		993	
Coal		10	993	10
Sandstone	3	2	997	
Shale, sandy	1		998	
Sandstone	5		1003	
Shale, sandy	19		1022	
Shale, blue	24		1046	
Sandstone	4		1050	
Shale, blue	1		1051	
Sandstone	26		1077	
Mississippian series:				
Limestone	39		1116	

CHAPTER VII.

NOTES OF THE FOSSIL FLORAS OF THE PENNSYLVANIAN IN MISSOURI.

Conditions of deposition of Missouri coals.—In the coal regions of Missouri fossil plants are relatively rare as compared with most other coal fields. This fact, which at first appears incompatible with the presence of so many beds of coal, each composed of the carbonized debris of plants, is due to the close proximity of the swamps, in which the coal-forming peat was laid down, to sea level. The coal swamps, which at most points are underlain by old soils still showing the roots of trees and smaller vegetal types in their places of growth, were in this part of the North American continent undergoing very slow depression while the mother peat was in the process of formation. In most areas the swamps sank below tide level before peat in sufficient thickness to form very thick beds of coal had been deposited. This appears fully to explain why the coals of Missouri are not thicker.

A close examination of the coal beds in most exposures shows that the process of peat building was interrupted by invasions of salt or brackish water from the sea, which killed the fresh water or terrestial plant types from which the peat was being formed. In many places the top of the peat was more or less decomposed in the sea water or mixed with inwashed silts, so as to form dirty cap-layers, or portions were re-deposited in the dark, thinly stratified carbonaceous muds generally termed "black slate" by the miners. In many places these black carbonaceous muds contain the shells of Lingula and Orbiculoidea, types that were able to live in very shallowly inundated mud flats rich in organic matter. Further subsidence, generally favoring the access of clearer sea water over the submerged peat swamps, permitted the invasion of a varied fauna of "shellfish," including pelecypods, brachiopods, bryozoans and corals, as well as fish. Remains, often in great abundance, of these animals are found in the shales immediately overlying the principal coal beds in the State. With greater clearness of the water, tho still with very shallow depth of the sea, there were laid down limestones or other lime-containing beds throughout the greater portion of the coal fields. These limestones, often spoken of as "cap-rocks", that overlie the coal beds, are largely composed of the remains of a great variety of invertebrate animals, as well as of sea weeds that inhabited the transgressing seas. In each case where sea deposits such as those just described were laid down over the peat swamps, the resumption of peat-building of the quality necessary for the formation of good coal could not take place until changes in the elevation of the land (which are always in progress) again brought the coal-forming areas above tide level, and so permitted the reoccupation of these areas by the peat-forming plant life.

It appears that when the peat deposits were submerged beneath the advancing sea, the rate of sedimentary deposition was so slow and the plants growing in the swamps were, in most areas, exposed so long to wave action and the agencies of decomposition, that only the more indestructible material, generally comminuted and waterworn, became buried so as to protect it from decay; hence in most places the roof shales covering the Missouri coal beds reveal little except spores, seed-coats, scales, and indeterminable parts of the stems and petioles of the plants that populated the swamps before the sea crept in. Here and there only was the subsidence of the swamp attended by such inwash of sediment from the land as to bury the fallen vegetation so as to preserve many of the ferns and other delicate plant forms from complete decay and destruction. Such deposition took place near Clinton, in Henry county, where at several of the mines large fragments of the fronds of ferns, some of which are very delicate and fragile, lie bedded in the shales like the dried plants between the sheets in an herbarium. The undestroyed plant substances are now converted to coal so that the actual fossil remains of the plants generally appear as black residues on the bedding surfaces of the shale.

Not rarely the butts of the trees growing on the surface of the peat swamp at the time of the killing by the salt water invasion decayed downward, forming hollow stumps which were filled with mud or sand while still standing upright in their places of growth. These filled stump cavities, which are generally surrounded by the thin coaly layer produced from the surviving resistant bark of the trees, form the "kettle bottoms" which are so frequent a source of danger in many of our coal mines.

In some instances the conditions of decay have been such as to favor the silicification of a part of the buried plant debris. Most notable examples of such silicification may be observed in the vicinity of Madison, Monroe County. Here we find many of the stumps of the trees standing in the roof of the ancient peat bog, now a coal bed, to have been completely silicified. Accordingly, as the erosion of the surrounding shales proceeds, the petrified stumps are revealed in all the aspect of slightly decayed, recently killed stumps, in their original position of growth. These remarkable petrified stumps are exactly similar in general appearance, in their relation to the underlying transformed fresh water peat, and in their envelopment by superposed brackish or salt water carbonaceous sediments to the stumps to be found on the surfaces of the submerged fresh water peats at many points along the New England coast, such, for example, as Vineyard Haven, on the island of Martha's Vineyard; the valley of the Mystic River near Boston, and the partially submerged peat swamps along the beach near Nahant, Mass. The conditions of growth, of killing, of decay, and of subsequent burial, are practically identical. However, the stumps standing in the fresh water peats along the New England coast are not petrified, the original wood being but slightly altered. In some areas, at least, they have not yet been completely buried.

In connection with the discussion of the marine submergence which generally attended the formation of the Missouri coals, it may, in passing, be noted that the high percentages of sulphides found in most localities in the coals of Missouri, Kansas, and Illinois, are believed by the writer to be largely due to the conditions of submergence of the organic matter, as described, and the attendant activities of sulphur fixing bacteria. It would appear that the elements necessary for the formation of the sulphides were, in the Eastern and Western Interior basins, contributed in relatively large amounts by the erosion of the rocks environing these basins.

The general physical conditions, including the physiography and climate, attending the formation of coal beds have been discussed somewhat fully by the writer in Bulletin 38 published by the Bureau of Mines. Therefore, he will here go no further in the discussion of this subject than to note that the fossil plants found associated with the coals of Henry County, which has furnished most of the paleobotanic material on which our knowledge of the coal flora of Missouri is based, indicate the existence of swamps in which tall trees of Lepidodendron, Sigillaria, and Calamites grew in areas partly covered by very shallow fresh water. Many of the associated herbaceous types, belonging mainly to Sphenopteris, Neuropteris, and Pecopteris, were large, some of them probably 30 feet or more in height. Others were slender, delicate-fronded types that climbed or clambered over the more robust species. The habit of these plants clearly indicates a tropical or sub-tropical climate, to which the large thin-walled cells of the wood, the absence of distinct annual rings, and the presence of structures adapted to the protection of the plants during dry seasons also point. The flora of the coals of Henry County contains some membranaceous types, but many of the fern-like plants, including forms of delicate tropical habit, are villous or even coriaceous. Accordingly, since the plants undoubtedly belonged to a swamp flora, it becomes probable that the xerophytic features were developed to enable the plants to withstand brief periods of lowering of the water level, i. e., short, dry seasons. That these dry seasons were not long, and that the general climate was amply humid, is shown by the structural adaptations of many of the types and by the formation of the peat itself.

Paleobotanical correlations.—While referring to the flora from the Henry County coals, the writer takes advantage of the opportunity to review and revise certain conclusions published in U. S. G. S. Monograph 37 as to the age of the plant bearing beds,—i. e., the shales over the coals at the Owen and Jordan coal banks and at Gilkerson's ford of Grand River:

At the time of writing the report mentioned above, when the floras of the different epochs in the type sections of the Pennsylvanian in the Appalachian trough were but little known, it was concluded that the flora from the coals of Henry County was probably to be correlated with that of the middle or Kittanning group of coals in the Allegheny formation, the suggestion being made that the Owen coal flora might perhaps be as young as the Upper Kittanning coal flora in Pennsylvania. Since 1898, the date of publication of that report, the writer has examined more fully the floras of the Allegheny formation, as well as those from many formations in the underlying Pottsville group, and it is in the light of these later studies that the following notes concerning the relations and the distribution of some of the species from the Henry County coals are brought especially to the attention of geologists and paleontologists.

Among the species described in Monograph 37 *Eremopteris bilobata* D. W., really a representative of the genus Cheilanthites of Göppert, is a survivor of the Cheilanthites of the upper Pottsville. Its latest near relative in America seems to be the *Cheilanthites (Sphenopteris) solida* Lx., which is probably nearly contemporaneous. The short, blunt, erose or denticulate lobes of *Eremopteris missouriensis* Lx. are in evidence of the descent of this species from the group represented in the Pottsville by the *Ecemopteris Cheathami* Lx. It is comparable also to *Sphenopteris Royi* Lx., from the middle Pottsville, and it finds close kinship in the plant from Coal "No. 2" of Illinois, recorded in the reports as *Sphenopteris spinosa* Goepp.

The approximation of the age of the coals worked near Clinton to the uppermost part of the Pottsville epoch is possibly shown in no group more closely than in the round-lobed Cheilanthites. The plant described by Lesquereux as *Pseudopecopteris obtusiloba* (Brongn.) Lx., plainly a Cheilanthites, is almost unknown in even the basal portion of the Allegheny formation in the Appalachian trough. It finds its closest relative in the Kanawha formation (upper Pottsville), where the species is developed in characteristic aspect. Mention should be here made also of the frond fragment with compact thick, round-lobed pinnules, shown in plate 7, figure 4 of the cited Monograph, which represents a plant possibly indistinguishable from an undescribed but widely distributed species of Cheilanthites that is characteristic of the upper Pottsville.

Of the species from the Henry County coals that have been referred to the genus Mariopteris, *M. sphenopteroides* (Lx.) Zeill. is best known in the flora of coal No. 2 in Illinois, while the fragment described as the "*Mariopteris* sp.", in plate 9 of the Monograph is very distinctly uppermost Pottsville in facies. Another species pointing toward a very late Pottsville date for the Henry County coals is *Crossotheca ophioglosoides* (Lx.) D. W., a plant almost unknown above the lowest horizon of the Allegheny formation. It belongs to a type characteristic of the highest coal of the Kanawha formation, namely, the Upper Mercer. Further, *Pecopteris vestita* Lx. represents a form that is now recognized as essentially characteristic of the Mercer coals, though it seems to be present also in the lowest portion of the Allegheny formation.

The plant described by Lesquereux as *Pecopteris Clintoni* has a close parallel in the Mercer coals, where is found also a species, possibly indistinguishable from *Pecopteris Jenneyi*, which at the time of its description was regarded by the writer as tending to show a rather late Kittanning age for the Henry County coal beds.

The Neuropteris described by Lesquereux as *N. missouriensis* belongs unquestionably to the *N. flexuosa* group, being but little removed from the latter species. It has no known representation above the Mercer coals in the Appalachian or other American coal fields. In this connection it may be remarked that *Linopteris Gilkersonensis* D. W. perhaps equals *Neuropteris missouriensis* in weight of evidence for the lower stratigraphic reference of the flora of the Henry County coals, since it, too, is highest Pottsville in facies. The genus *Linopteris* is unknown below the Mercer coals.

Passing from the Cycadofilices and ferns to the other plant groups described from Henry County we note that types possibly indistinguishable from *Sphenophyllum fasciculatum* (Lx.), seem to be rare if actually present in post-Pottsville beds.

On the other hand there are in the flora of the Henry County coals many plants such as *Callipteridium Sullivanti* (Lx), Weiss, which are, in general, to be regarded as indicative of Allegheny age. Other species, such as *Sphenopteris mixta* Schimp, *Oligocarpia missouriensis* Lx., a very large and rather delicate type, and *Alethopteris ambigua* Lx., suggest an horizon very low in the Allegheny. It may be noted also that *Callipteridium Sullivanti*, though apparently confined to the Allegheny formation, seems most at home near coal "No. 2" in the Eastern Interior Basin.

From the foregoing it will be seen that the evidence of the fossil plants, as interpreted according to our present knowledge of the Pennsylvanian flora, indicates for the Henry County coals an horizon at the base of the Allegheny formation, if not, as seems slightly more probable, in the uppermost portion of the Pottsville.

The flora of the Bevier coal in the region north of the Missouri River is not well known, but a small collection of fossil plants has fortunately been gathered from this horizon at Bevier. Since this later-collected paleobotanical material has not yet been systematically studied and compared, the correlative conclusions based upon its preliminary inspection are but tentative. It appears, however, from a superficial examination of the plant material from this horizon, that the Bevier coal is probably very closely contemporaneous with, if not actually identical, with the Murphysboro coal ("No 2") of western Illinois, which undoubtedly is of very nearly the same age as the Brookville coal, at the base of the Allegheny formation in the Appalachian trough, and which in Illinois is, with its underclay, made the base of the Carbondale formation. This tentative correlation, based upon the fossil plants, has, in the judgment of both Mr. Henry Hinds and the writer, found a measure of corroboration in the stratigraphic features of the beds enclosing the coal.

The somewhat meagre material secured from the roof of the Bevier coal does not seem to include such a representation of the more ancient elements in the flora of the Henry County coals as would naturally be expected were the latter coals equal to or later in age than the Bevier coal. It is therefore reasonable to conclude that the Henry County coals, (Owens and Jordans Banks) are not younger than the Bevier coal. On the other hand, it appears slightly probable that they are, in fact, a little older. A direct comparison of the flora of the Jordan coal in Henry County with that of the Murphysboro coal in Illinois likewise leads to the provisional conclusion that the former is slightly earlier in age, thus tending to favor its reference to the uppermost Pottsville, to which epoch, in the light of the information obtained since 1898, it is accordingly tentatively assigned by the writer.

The paleobotanical evidence now available, though not fully investigated, points toward the correlation of the Bevier coal in northern Missouri with coal "No. 2", the Murphysboro bed, which with its underclay forms the base of the Carbondale formation in Illinois.

CHAPTER VIII.

INVERTEBRATE PALEONTOLOGY.

BY GEORGE H. GIRTY.

DISCUSSION OF FAUNAS.

The collections on which this discussion of the invertebrate paleontology is based are the work of many hands. By far the largest number were procured by Mr. F. C. Greene, though others shared in the work. Much of the Cherokee material was collected for the United States Survey by Mr. Gilbert Van Ingen. In all, the collections upon which this report is based amount to 253, and they include representatives of nearly 350 species. The largest number from one formation is 53, from the Cherokee shale, and the most varied fauna is that of the Douglas formation, which contains 148 species; the Kansas City formation with seven more collections lacks only 4 or 5 species of containing an equal number. The following list shows these data by formations:

	Collections.	Species.
Wabaunsee formation	4	9
Shawnee formation	20	100
Douglas formation	40	148
Lansing formation	35	114
Kansas City formation	47	143
Pleasanton formation	19	74
Henrietta formation	35	83
Cherokee shale	53	120
Total	253	

The mere handling of so much material, aggregating many thousands of specimens, has been a task of large proportions and I have received some help both from Mr. Greene and from Mr. P. V. Roundy, by whom some of the collections were separated and identified. All identifications were carefully reviewed by me, however, except a few species of fenestelloids determined by Mr. Greene.

It may be worth while to consider what object is sought in such work as this, whether the object has been attained in the present instance, and whether the results justify labors so considerable. Although a certain number of new species were discovered in the course of this investigation they by no means furnished the motive for the work, nor would they be any adequate return for that which has been performed. Indeed, it would have been practicable to pick out the new species and describe them without doing much of the work which was done.

The desirability of supplementing such careful stratigraphic work carried on over so wide an area by a report on the fossils obtained, and the opportunity of making a comprehensive study of faunas of so extensive a section under such favorable conditions, were the actuating considerations for an undertaking of which the results make but a small showing for the time and pains demanded. Although considerable attention has been given to this same line of research in the neighboring state of Kansas, the present investigation, which concerns a different though contiguous area, promised both to add to the other and to furnish a check upon it.

In all nearly 350 species have been recognized in our collections from the Pennsylvanian rocks in Missouri. Besides ascertaining the range of these species in the section and their varying assemblages into the formational faunas, an interesting field of research would be to trace the changes which some of the long-lived species underwent, changes which might not warrant, or at least have not warranted, recognizing them as more than a single species, but which might prove to have a fixed place in the sedimentary record and thus to be capable of serving as an index, when checked by other evidence, of the age of any fauna brought into question. A typical species for an investigation of this sort would be *Composita subtilita*, under which are united quite a variety of kindred and connected forms, which no one has as yet had the hardihood to distinguish and to name. Probably they are not separate species, but probably some of them would be found to have a place in the development of the type in geologic time. From the enticements of this field of research I have had to turn away, the lack of time and the pressure of other duties preventing me from entering it. My work has thus perforce been prosecuted along broader or at least other lines and is conditioned on the acceptance of most of the specific units as with their time-honored boundaries.

The best method of conducting an investigation such as this, is to break up each collection into its constituent species, and to assemble for study at one time the specimens of each species from all the localities at which it has been found. Besides opening the way to a complete and comprehensive study of every species, this method enables one to identify many specimens otherwise indeterminable by establishing a reasonable specific identity with better specimens which are determinable. It crystallizes the specific concept while confusing the faunal concept. This method for several reasons I have not adopted here. The species have been identified collection by collection, but although this has been a slight disadvantage, sufficient care has been exercised and sufficient checks have been applied to make the identifications accurate and consistent. In certain groups greater refinement is both desirable and possible. My treatment of the Fusulinas is very inadequate and my determinations of many of the Bryozoa unsatisfactory. Both groups require special study by means of thin sections and constitute little problems by themselves, but their investigation was not vital to my purpose and I could not command the time to undertake it. It must not be understood, however, that many of the Bryozoa have not been thin-sectioned and much study given to their identification.

In choosing the form of presentation of the evidence in such a study as this for the judgment and use of other paleontologists, much depends on the nature of the case. If the faunas have been little studied and have a more or less peculiar facies with many of the forms doubtfully identical with described species, it is almost necessary to furnish illustrations and detailed descriptions which may serve as vouchers for the identifications and for the conclusions in correlation that are based upon the identifications. This method is less essential in the present case, for Missouri is part of the paleontologically best-known Carboniferous area of America and most of the species found in the collection are common and have been described and figured over and over again. Consequently it has been thought necessary to figure or describe in the present paper only the new species or those about which some question had arisen.

Most of the features that invite comment in these faunas are mentioned under the formations in which they are exhibited. As in Kansas so here the rocks forming the geologic column of the Pennsylvanian consist of alternate limestones and shales. Many of them were originally regarded as formations and named as such, but here they are considered as members of larger groups which are designated formations and to which they are severally assigned. It has been noted in the Kansas section, and is equally true of this, that but few of the shale members are fossiliferous and that most of the invertebrate fossils occur in the limestone members. It has sometimes been held, and reasonably so in so far as faunal facies are governed by habitat, that one type of fauna, broadly speaking a molluscan fauna, occurs in shale formations and another type of fauna, a molluscoidean fauna, occurs in limestone formations. To some extent this generalization is borne out by the collections from the Missouri coal field. That it is not more amply supported by this evidence may be due to several causes. The conditions that determined the deposition of beds of shale or of limestone are probably only one of the factors that determined the character of the marine animals found in them. Again it is fairly certain that all Mollusca, or all Molluscoidea, were not adapted to one environment. Certain types of the one doubtless throve best in the environment generally most suited to the other. It is also not improbable that many of our fossils have been swept by currents from the place where they lived and died, into an alien and unfavorable environment. Furthermore, although the sedimentary record, as I have already mentioned, is expressed lithologically in terms of alternating shales and limestones, there is of necessity some limestone in the shale members and some shale in the limestone members, so that if we had the complete facts at our disposal the theory might receive even more support than now appears. However that may be, as represented in my collections, some of the shale faunas abound in brachipods and some of the limestone faunas are relatively speaking rich in pelecypods. Indeed, to a certain extent the formations here considered expressed themselves biologically in faunas in which the molluscan and molluscoidean elements predominate alternately, although in the formations as a whole one kind of rock does not seem to prevail and the fossils themselves were derived chiefly from the limestone members. Too little attention has been paid to the relationship between fossil faunas and their environment expressed in terms of lithology, although the subject forms an attractive, if difficult, field of investigation.

The occurrence at different horizons of dwarf faunas, or faunas in which most of the species are of conspicuously diminutive size, has long been the subject of comment. In so far as my personal experience goes, these faunas are relatively rich in pelecypod and gastropod types, and although brachiopods may be numerous as individuals, they are apt to be below normal in variety, at least in comparison with the molluscan representation. Such a fauna is one that was collected at Kansas City in the Kansas City formation, and that introduces into the fauna of the Kansas City formation, otherwise composed largely of brachipods, a noteworthy assemblage of pelecypods and gastropods. Faunas of this type occur usually in an oölitic rock and this holds true of the collection immediately under discussion. It is not, however, true that all faunas that existed under conditions conducive to the formation of oölites were subnormal in size. It is interesting to remember that the Kansas City occurrence is supposed to be at the horizon of the Drum limestone of Kansas. At the typical locality of the Drum, however, the Drum limestone is conspicuously oölitic, yet the fauna which it contains is not only abundant but peculiarly robust in the size of its individuals.

CHEROKEE SHALE.

This, the basal formation of the Pennsylvanian in this region, is at once the thickest of the section and also that from which the largest number of collections has been made. These are 53 in number, while the number of species entered in the table is 120.

Taken as a whole the fauna is more well-balanced than many which occur in the Pennsylvanian, the three great groups of brachiopods, pelecypods, and gastropods being well represented, the former somewhat less, the two latter more abundantly than usual. The almost complete absence of Bryozoa, even of the fenestelloids, is noteworthy.

If I were to give a zonal name to this formation because of some ever-present and ever-abundant species, I would call it the *Marginifera muricata* zone both because that species is so persistent in this fauna and because it is found sparingly at higher horizons. As is not unusual where small Producti are abundant, the larger types are less well represented. This is true to some extent of the fauna as a whole but is still more true of individual faunules in which the Marginiferas are abundant and the larger Producti scarce or absent (e.g. *Pustula semipunctata*). Some of the other common Pennsylvanian types of brachiopods also are scarce or absent altogether. Among the rare forms, Meekella, and among the absent ones, Enteletes, are perhaps most conspicuous. Even the ubiquitous *Composita subtilita* is not as a rule abundant. On the other hand, *Chonetes mesolobus* or the variety *decipiens* is persistently present. The appearance of conodonts also at this horizon is a new and striking feature.

When considering the significant Brachiopoda, I must not fail to mention *Spirifer rockymontanus* which is undoubtedly present in the lowest fauna of both the northern and southern areas, though it is rare. *Spirifer rockymontanus* is abundant in the Rocky Mountain region and westward; it is abundant elsewhere in the Mississippi Valley at a lower and possibly at the same horizon as the Cherokee shale, and it is also abundant in the Appalachian region. Its almost complete absence then from the Pennsylvanian rocks of Kansas and Missouri is a very striking thing. That it does occur in the basal rocks of this section is a fact which tends to give it stratigraphic rather than regional significance. In Pennsylvania *Spirifer rockymontanus* is abundant in the Allegheny formation but Professor Raymond does not record it from the Conemaugh. The present occurrence then would suggest that the Cherokee shale was as young as the Allegheny formation, an inference with which the rest of the invertebrate evidence is at least not at variance.

Conspicuous among the local collections is a gastropod fauna which was obtained from the lower part of the formation and in the southern area. This is exemplified by lot 1268A2, of which the gastropods comprise no less than 18 out of the 27 species recognized, or two-thirds of the whole fauna. These chiefly belong to the groups of Naticopsis, Bulimorpha, and Loxonema, and for the most part their appearance in the fauna is confined to this one occurrence.

TABLE SHOWING RANGE AND DISTRIBUTION OF SPECIES IN THE CHEROKEE SHALE.*

Species	Near local base	Lower Ardmore coal horizon	Bevier coal horizon	Mulky coal horizon*	Mulky coal horizon	Summit coal horizon	Lexington coal horizon	Lower 100-200 feet	100 feet from top	70-80 feet from top
Fusulina sp. cf. cylindrica										1
Cyrtyina ventricosa			1	1	1				2	1
Amplexus sp.										1
Lophophyllum profundum			2	1	1			1	1	1
Campophyllum torquium*				1						
Chaetetes milleporaceous				2	1					1
Eupachycrinus tuberculatus								1		1
Serpulopsis insita			3	1						1
Enchostoma sp.										1
Conodonts					2					
Fistulipora carbonaria			1	2						
Fistulipora sp.	1									
Batostomella polyspinosa									1	
Batostomella greeniana	2					1				
Batostomella sp. A			1				1			
Tabulipora aff. ohioensis				1						
Tabulipora distans				1						
Fenestella sp.				1						
Rhombopora lepidodendroides				1					1	2
Prismopora triangulata				2						
Prismopora sp.	1									
Lingula carbonaria			2		1					
Lingula umbonata										
Lingulodiscina missouriensis		1	1	1	2	1		4	1	1
Derbya crassa	1	1	1	3	1	3	1	2	3	4
Derbya robusta*										1
Meekella striaticostata				2						
Chonetes granulifer			1							
Chonetes mesolobus			4			1		2	2	2
Chonetes mesolobus var. decipiens	1		7	4	2	3	1	1	2	4
Chonetes verneuilianus	1		3	2	1	3			1	1
Productus cora	1		2	2	1	1	1	4	3	4
Productus semireticulatus	1		5	2	2	1	1	1	2	4
Productus pertenuis						1				
Pustula gallatinensis*	1					1				
Pustula nebraskensis	1		1	2	2	2		2	1	1
Pustula semipunctata	1			1						
Marginifera muricata	1	1	5	1	3	4		1	3	4
Marginifera muricata var. missouriensis								5		
Marginifera splendens			2	3	1	1				
Marginifera wabashensis						1				
Pugnax osagensis		1								1
Pugnax osagensis var. percostata										1
Pugnax rockymontana								2		
Spirifer cameratus	1		5	4	2	1		2	1	4
Spirifer rockymontanus	1							1		1
Ambocoelia planiconvexa		1	4		2			1	1	2
Squamularia perplexa				2	3	2		3		2
Spiriferina kentuckyensis			1	1				1	1	1
Hustedia mormoni					1			1	1	
Cleiothyridina orbicularis	1		2	1						1
Composita subtilita	2	1	4	4	2	4	1	1	1	5
Solenomya soleniformis					1					
Solenomya trapezoides					1					
Cardiomorpha missouriensis								2		
Edmondia gibbosa?									1	
Edmondia sp.			1							1
Nucula parva*								1		
Nuculopsis ventricosa*			2							
Parallelodon tenuistriatus*									1	
Pteria sulcata*									1	
Myalina perniformis*	1									
Aviculipecten pellucidus					1					
Aviculipecten rectilaterarius			3		2					
Aviculipecten aff. rectilaterarius					1					
Aviculipecten whitei			1							
Aviculipecten sp.					1					
Pernipecten aviculatus					1			2		
Acanthopecten carboniferus									1	
Euchondria neglecta					1					
Lima gregaria*					1					
Lima retifera					1					
Pleurophorus? tricardinalis								1		
Allorisma terminale						1				
Astartella concentrica					1				2	1
Astartella compacta					1					1
Astartella sp.										
Euphemus carbonarius			1		1			1	1	1
Pharkidonotus percarinatus			1		1			2		
Patellostium montfortianum					1					
Pleurotomaria persimplex										1
Murchisonia missouriensis										1
Phanerotrema grayvillense			1		2	1		1		1
Trepospira depressa								1		1
Trepospira sphaerulata*								1		
Schizostoma catilloides									1	
Naticopsis altonensis				1						1
Naticopsis nana										1
Naticella americana										1
Zygopleura affinis										1
Zygopleura multicostata										1
Zygopleura parva*										1
Zygopleura plicata										1
Zygopleura sp.					1					
Hemizyga dulcis										1
Hemizyga elegans										1
Hemizyga grandicostata										1
Bulimorpha chrysalis								1		1
Bulimorpha inornata										1
Bulimorpha minuta										1
Bulimorpha* sp.									1	
Sphaerodoma* fusiformis						1				
Sphaerodoma gracilis*										1
Sphaerodoma sp.			1	1						
Meekospira peracuta			1							
Meekospira* sp.									1	
Aclisina stevensana*							1			
Aclisina* sp.					1					
Trachydomia wheeleri										2
Orthoceras sp.			1		1					
Pseudorthoceras knoxense					1					
Metacoceras aff. cornutum			4		1					
Nautilus sp.					1					
Gonatites sp.					1					
Gastrioceras welleri*								1		
Primitia sp.*								1		
Hollina sp.			1							
Bairdia aff. beedei					1					
Bairdia sp.							1			
Cytherella sp.			1		2	1	1			

*The numbers at the head of the columns indicate localities which are described in the locality register on page 364. The final columns show the faunas found at the different horizons in the Cherokee, and are composed as follows: Near local base—comprising lots 260, 264. Lower Ardmore coal—comprising lot 261. Bevier coal horizon—comprising lots 230, 238, 257, 258, 268, 271, 287, 309, 649. Mulky coal horizon (doubtful)—comprising lots 192, 307, 307a, 307b, 1256A₁. Mulky coal horizon—comprising lots 244, 267, 269, 270, 433, 1256B, 1256B₁. Summit coal horizon—comprising lots 187, 209, 263, 668, 670, 1260A₁, 1260A₂, 1260A₃. Lexington coal horizon—comprising lot 262. Lower 100 to 200 feet—comprising lots 1263A₁, 1264A₁, 1263B₁, 1263C, 1263C₁, 1263C₂+, 1263C₃. One hundred feet from the top—comprising lots 255, 255a, 1269A₁. Seventy to eighty feet from top—comprising lots 241, 242, 254, 708, 1268A₁, 1268B₁, 1268C₁, 1268D₁.

HENRIETTA FORMATION

To the Henrietta formation have been referred 35 collections distributed thus: Pawnee limestone member 8 lots, Labette shale member 2 lots, and the Fort Scott limestone member 25 lots.

The accompanying table shows the species identified in each collection and the final columns give the faunas of the three members as obtained by grouping the individual lots in the manner indicated. The whole formation as represented in our collections has a fauna of 83 species, of which no less than 78 have been found in the Fort Scott limestone, 11 in the Labette shale, and 32 in the Pawnee limestone. All but 5 of the Pawnee species have been found in the Fort Scott limestone. Neither the species newly introduced into the Labette shale nor those first appearing in the Pawnee limestone are of much significance, being unidentified or doubtfully identified (as Aviculipecten sp.), or represented by single specimens (as *Sanguinolites costatus* and *Dielasma bovidens*).

Compared with the fauna of the Cherokee shale that of the Henrietta formation is much less varied and in especial it contains a much smaller representation of the true Mollusca. Of the Cherokee the rich pelecypod and gastropod faunas are striking features. In neither formation do the cephalopods show either number or variety, at least in so far as my collections correctly represent the fact.

It is perhaps noteworthy that the Fusulinas are found in both formations, modestly perhaps, yet persistently. The corals show little that is noteworthy except the presence in both formations of *Chaetetes milleporaceus*, a fossil which seems to be rather characteristic of this general horizon and which is abundant in the Fort Scott and Pawnee limestones at their typical localities. Crinoids are rare in both formations and are represented only by separate plates and stems. From such sporadic representation no safe inference can be drawn. Much the same must be said of the Bryozoa which are rather scanty, fragmentary, and poorly preserved. The presence in both faunas of the interesting species *Prismopora triangulata* seems deserving of comment.

In the Henrietta formation and to a less degree in the Cherokee the brachiopods form the dominating faunal element. The species are much the same in both but several features are worthy of mention. The absence of *Pustula semipunctata* in the Henrietta formation is singular though probably not significant since it comes in again at higher horizons. The abundance of *Marginifera muricata* in the Cherokee has already been noted. It is found also in the Henrietta formation but in much fewer collections and in much less abundance. Still among the Productoids, the presence of Tegulifera (probably *T. kansasensis*) in the Henrietta fauna is of interest. The absence of *Spirifer rockymontanus* in that fauna is not only interesting but significant for it is abundant at lower horizons, occurs also in the Cherokee but, so far as my experience extends, it does not appear again in this region. The rest of the spire-bearers demand no comment. They represent the same species and are abundant in both formations. *Pugnax rockymontana* in the Cherokee and *Cryptacanthia compacta* in the Henrietta are rare types in this region and interesting on that account, but because of their rarity their significance must not be accounted great until their range is better known.

The Cherokee fauna shows 25 species of pelecypods as against 7 in the Henrietta, and 31 species of gastropods as against 7 in the Henrietta, a number of species in both faunas, be it noted, being unidentified. In the main the pelecypods and gastropods of the two faunas are different. The representation is so unequal, however, as to discourage inference. *Clinopistha radiata* var. *levis* and *Cardiomorpha missouriensis* (which occurs also in the Cherokee fauna) are noteworthy occurrences in the Henrietta.

Considered by themselves the collections of the Henrietta formation have little of note, being much alike in their specific content and presenting a facies monotonously familiar in the Pennsylvanian. An interesting exception is the collection from 1254B1 which is supposed to represent an horizon close to the Fort Scott limestone. The fossils occur in a dense and very fine limestone which, if not weathered, is intensely black in color. Small coiled shells a millimeter or so in diameter fairly crowd this rock and seemingly represent the larval stages of 2 or 3 species of Goniatites, of which some of the larger shells have been identified as *Gastrioceras welleri* and *Milleroceras parrishi?*.

Cardiomorpha missouriensis also is abundant. *Lima gregaria* is rather rare and two gastropod types are represented by a poorly preserved specimen each. Altogether the like of this little fauna is not found elsewhere in the collections.

TABLE SHOWING RANGE AND DISTRIBUTION OF SPECIES IN THE HENRIETTA FORMATION.*

Species.	Localities.																		
	175	203	204	232	234	235	239	240	243	245	247	248	249	251	252	253	256	259	264
Fusulina secalica																			×
Fusulina sp.																			
Girtyina ventricosa									×						×			×	
Axophyllum cylindricum																			
Lophophyllum profundum	×		×			×	×			×			×				×		
Monilipora prosseri																			
Chaetetes milleporaceus																			
Echinocrinus sp.				×															
Hydreionocrinus acanthophorus										×									
Hydreionocrinus mucrospina			×							×									
Ceriocrinus? sp.	×																		
Eupachycrinus tuberculatus																			
Serpulopsis insita		×												×					
Spirorbis carbonaria										×									
Fistulipora carbonaria										×						×			
Fistulipora carbonaria var.																			
Fistulipora nodulifera													×						
Fistulipora sp.											×								
Batostomella polyspinosa			×	?															
Batostomella greeniana							×			×							×		
Batostomella sp. A																			
Ioclema? sp.				×															
Tabulipora distans			×										×						
Tabulipora sp.																		×	
Liopora subnodosa										×				×					
Fenestella tenax																		×	
Polypora sp.													×					?	
Pinnatopora sp.																			
Rhombopora lepidodendroides											×						×		
Prismopora triangulata																			
Crania modesta													×						
Derbya bennetti	?										?								
Derbya broadheadi?																			
Derbya crassa		×	?	×									×			×	×	×	
Orthotetes? sp.				×									×						
Meekella striaticostata				×	×								×					×	
Chonetes granulifer	×		×	×	×				×	×		×	×					×	
Chonetes mesolobus		×										?				×			
Chonetes mesolobus var. decipiens	×	×	×	×	×		×			×	×	×	×	×			×	×	

Species.	308	310	310a	660	661	662	666	667	669	674	707	1254 loose.	1254B	1255B	1266A	1266A₂	Fort Scott limestone member.	Labette shale member	Pawnee limestone member.
Fusulina secalica												×					2		
Fusulina sp.							×										1		1
Girtyina ventricosa										×							4		
Axophyllum cylindricum																			1
Lophophyllum profundum	×				×		×										7		2
Monilipora prosseri				×													1		
Chaetetes milleporaceus				×													1		
Echinocrinus sp.																	1		
Hydreionocrinus acanthophorus																	1		
Hydreionocrinus mucrospina																	1		1
Ceriocrinus? sp.																			2
Eupachycrinus tuberculatus		×																1	
Serpulopsis insita					×		×	×	×								7		
Spirorbis carbonaria																	1		
Fistulipora carbonaria																	1		2
Fistulipora carbonaria var.									×								1		
Fistulipora nodulifera																	1		
Fistulipora sp.																	2		
Batostomella polyspinosa																	1		1
Batostomella greeniana																×	3		1
Batostomella sp. A					×			×	×								3		
Ioclema? sp.																	1		
Tabulipora distans																	1		1
Tabulipora sp.																	1		
Liopora subnodosa																	2		
Fenestella tenax								×									2		
Polypora sp.									×								3		
Pinnatopora sp.										×							1		
Rhombopora lepidodendroides					×					×							4		
Prismopora triangulata								×	×	×	?						4		
Crania modesta									×								2		
Derbya bennetti								×									2		1
Derbya broadheadi?								×			×						2		
Derbya crassa					×		×		×	×							9		2
Orthotetes? sp.																	2		
Meekella striaticostata					×				×		×						7		
Chonetes granulifer			×		×		×		×	×	?					×	11	1	4
Chonetes mesolobus										×							2	1	1
Chonetes mesolobus var. decipiens	×	×			×	×	×	×	×		×					×	16	2	4

Chonetes mesolobus var. euampygus																	×	×											×							3		
Chonetes verneuilianus																	×																			1		
Productus cora			×	×									×				×	×						×			×									6		1
Productus costatus?		×	×																								×								×	2		2
Productus pertenuis										×								×																		2		
Productus semireticulatus	×			×			×			×			×					×			×			×				×		×				×		9	1	1
Pustula nebraskensis										×			×														×			×					×	4		1
Pustula symmetrica											?																	?								2		
Pustula semipunctata																														×						1		
Marginifera muricata							×							×								×														2		1
Marginifera splendens	×		×							×	×						×				×	×		×		×		×	×						×	7	1	4
Marginifera wabashensis?							×																													1		
Strophalosia spondyliformis				×									×																							2		
Tegulifera kansasensis																						×									?		×	?		2		2
Pugnax osagensis	×																							×		×			×							3		1
Cryptacanthia compacta																															×					1		
Dielasma bovidens			×																																			1
Spirifer cameratus		×	×	×	×					×			×				×	×	×		×			×				×		×				×		12	1	1
Ambocoelia planiconvexa	×		×									?		×			×	×						×		×		×	×						×	7	1	3
Squamularia perplexa	×		×		×					×		×					?		×			×		×		×		×			×		×	×		9	1	4
Spiriferina kentuckyensis	×									×			×				×	×						×		×			×							7		1
Hustedia mormoni					×														×		×					×					×					4	1	
Cliothyridina orbicularis	×			×	×		×			×	×		×	×						×						×			×		×					10		2
Composita subtilita	×	×	×	×	×					×	×	×	×					×	×		×	×		×		×	×	×		×	×			×	×	15	2	4
Sanguinolites costatus																						×																1
Clinopistha radiata var. levis																															×					1		
Cardiomorpha missouriensis																															?	×				2		
Leda arata																																			×			1
Aviculipecten sp.																														×					×	1		1
Lima gregaria																																×				1		
Allerisma terminale																										×								×		2		
Bucanopsis bella				×																																1		
Euphemus carbonarius		×																																		1		
Pleurotomaria sp.																																×				1		
Phanerotrema grayvillense		×																																		1		
Zygopleura sp.		×																																		1		
Aclisina quadricarinata																																?				1		
Orthoceras sp.								×																												1		
Milleroceras parrishi?																																×				1		
Gastrioceras welleri																																×				1		
Phillipsia major?				×																																1		
Bairdia aff. beedei																											×									1		
Bairdia? sp.																								×												1		
Cytherella? sp.																									×											1		

*The numbers at the head of the columns indicate localities which are described in the locality register on page 364. The final columns show the faunas found in the different members of the formation and are composed as follows: Fort Scott limestone member—comprising lots 203, 232, 234, 239, 240, 243, 245, 247, 249, 251, 252, 256, 259, 264, 660, 661, 662, 666, 667, 669, 674, 707, 1254 loose(?), 1254B(?), 1266A$_1$. Labette shale member—comprising lots 248, 310. Pawnee limestone member—comprising lots 175(?), 204, 235, 253, 308, 310a, 1255B$_1$, 1266A$_2$(?). Lot 175 has been included in the Pawnee collections because its stratigraphic position appears to be in the upper part of the Henrietta formation. Faunally this lot agrees better with the Fort Scott. Lot 177 which does not certainly belong in the Henrietta formation, and several lots whose position in the Henrietta is not certain, have been tabulated with the fauna of the Fort Scott limestone member as their most probable position.

PLEASANTON FORMATION.

The collections from the Pleasanton formation are 19 in number and contain representatives of 74 species. Of the 19 collections 5 are from southern Missouri and 14 from northern Missouri, and of the 74 species 33 are from the southern and 55 from the northern part of the State. The fauna of this formation shows considerable geographic differentiation, only 14 species being held in common by the northern and southern collections. This means that over 51 per cent of the southern fauna and over 74 per cent of the northern is peculiar to one and excluded from the other. The southern fauna is strong in crinoids, bryozoans, and brachiopods but weak in the true molluscs. The northern fauna, on the other hand, is strong in the true molluscs but weak in the other types. This is well shown by the table.

If we consider the southern fauna more particularly, 4 of the 5 collections are from the lower shale, regarded as probably representing the Bandera shale of Kansas, and one is from a limestone regarded as probably representing the Altamont limestone of Kansas, and of the 33 species comprised in the collections only six were found in the limestone and every one of these occurs also in the shale. These two members are not, however, distinguishable in the northern part of the State, but the formation is there parted by a conspicuous unconformity above which 4, and beneath which 10 of our 19 collections were obtained. This break in sedimentation does not seem to find any noteworthy expression faunally. The beds above the unconformity have yielded us only 13 species of which 8 were collected also below the unconformity. The five forms which as yet have not been found below it are not diagnostic in any way, are in fact mostly undetermined species.

As compared with the fauna of the underlying Henrietta formation, this shows the differences to be found between two faunas in which the Mollusca and Molluscoidea, respectively, predominate. In this respect the Pleasanton fauna of the south is much more like the Henrietta fauna than is the Pleasanton of the north. The lower organisms show little of contrast in the two formations. The Bryozoa and brachiopods are much more richly developed in the Henrietta than in the Pleasanton. Most of the Pleasanton species, however, occur in the Henrietta also, and most of the Henrietta species which are not recorded in the Pleasanton come in again at higher horizons. On the other hand the pelecypods and gastropods are abundant and varied in the Pleasanton, but rare in the Henrietta and what is more the Henrietta gastropods and pelecypods are not those of the Pleasanton but show in fact much that is peculiar whether comparison is made with the Pleasanton or with later faunas.

TABLE SHOWING RANGE AND DISTRIBUTION OF SPECIES IN THE PLEASANTON FORMATION.*

Species.	Localities.																			Northern Missouri		Southern Missouri	
	202	231	236	236a	237	246	265	430	647	648	653	654	655	664	665	671	672	673	675	Below unconformity.	Above unconformity	Lower shale (Bandera?)	Limestone (Altamont?)
Fusulina secalica			X																			1	
Axophyllum cylindricum								X	X											1	2		
Lophophyllum profundum		X	X	X	X	X	X		X				X			X	X			5	1	4	1
Chaetetes milleporaceus									X												1		
Hydreionocrinus acanthophorus			X	X			X															3	
Hydreionocrinus mucrospina							X															1	
Ceriocrinus fayettensis?							X															1	
Eupachycrinus tuberculatus				X																		1	
Serpulopsis insita				X		X	X			X		X								5		2	
Spirorbis carbonaria										X										1			
Fistulipora carbonaria				X																		1	
Batostomella greeniana		X		?					?								?			1	1	2	
Rhombopora lepidodendroides		?																				1	
Derbya bennetti?			X	X																		2	
Derbya crassa	?	X		X		X	X				X		X			X	X			6		3	
Chonetes geinitzianus?																	X			1			
Chonetes granulifer	X	X	X	X	X		X	X			X	X			?	X		X		5	2	4	1
Chonetes mesolobus				X																		1	
Chonetes mesolobus var. decipiens		X		X			X	X													1	3	
Chonetes verneuilianus						X														1			
Productus cora						?						X						X		3			
Productus pertenuis						X					X	X	X		?					4	1		
Productus semireticulatus				X																		1	
Pustula nebraskensis																				1			
Pustula semipunctata				X																		1	
Marginifera splendens	X	X	X	X	X	X	X		X								X			3	1	4	1
Pugnax osagensis		X		X																		2	
Spirifer cameratus		X	X	X			X	X									X			1	1	4	
Ambocoelia planiconvexa		X	X			X	X		X							X				2	1	3	
Squamularia perplexa			X																			1	
Spiriferina kentuckyensis		X	X		X																	2	1
Hustedia mormoni		X		X	X																	2	1
Cliothyridina orbicularis								X													1		
Composita subtilita	X								X								X			2	1		
Edmondia glabra?	X																			1			
Edmondia ovata	X																			1			

Edmondia reflexa											×									1			
Edmondia? sp.																×				1			
Nucula anodontoides																		×		1			
Nucula sp.	×																			1			
Nuculopsis ventricosa?						×														1			
Leda meekana																×				1			
Parallelodon sp.																		×		1			
Schizodus rossicus?										×										1			
Aviculipecten aff. pellucidus										×										1			
Pernipecten aviculatus												×								1			
Acanthopecten carboniferus?												?								1			
Astartella concentrica						×				×			×			×		×	×	6			
Bellerophon crassus var. wewokanus?				×																		1	
Patellostium montfortianum				×		×				×			×					×		4		1	
Bucanopsis meekana				?		×														1		1	
Euphemus carbonarius										×	×		×			×		×	×	6			
Pharkidonotus percarinatus						×														1			
Murchisonia? sp.									×												1		
Phanerotrema grayvillense						×							×			×		×	×	5			
Trepospira sphaerulata						×				×	×	×	×		×	×		×	×	8	1		
Orestes nodosus													×							1			
Schizostoma catilloides													×			×				2			
Naticopsis altonensis	×																			1			
Sphaerodoma brevis				×												×		×		2		1	
Sphaerodoma intercularis															?						1		
Sphaerodoma primigenia										×	×	×			×					3	1		
Sphaerodoma ventricosa?				×																		1	
Sphaerodoma? sp.						×														1			
Meekospira peracuta						×							×						×	3			
Meekospira? sp.														×							1		
Pseudorthoceras knoxense				?		×				×	×	?	×			×		×		7		1	
Goniatites sp.												×						?	×	3			
Phillipsia major																	×			1			
Griffithides sp.						×										×				2			
Kirkbya centronata							×															1	
Bairdia beedei					×		?			?						?				2		1	1
Bairdia sp.			×																			1	
Cytherella sp.	×					×														2			

*The numbers at the head of the columns indicate localities which are described in the locality register on page 364. The final columns show the faunas found in the different members of the formation and are composed as follows: Northern Missouri, below the unconformity—comprising lots 202, 246, 648, 653, 654, 655, 671, 672, 673, 675. Northern Missouri, above the unconformity—comprising lots 430, 647, 664, 665. Southern Missouri, lower shale (Bandera?)—comprising lots 231, 236, 236a, 265. Southern Missouri, Altamont limestone(?)—comprising lot 237.

KANSAS CITY FORMATION.

The Kansas City formation includes in ascending order the following members: Ladore shale, Hertha limestone, Bethany Falls limestone, Galesburg shale, Winterset limestone, Cherryvale shale, Drum limestone, Chanute shale, and Iola limestone. As usual the shale members have proved scantily fossiliferous, most of the 47 collections having come from the limestones. To this an exception must be made of the Chanute shale with its two limestone lentils and the Cherryvale shale. The different collections are distributed in the nine members of the Kansas City formation as follows: To the Hertha limestone belong lots 233 and 423; the Ladore shale has furnished no fossils; the Bethany Falls limestone has given lots 201, 250, and 419; the Galesburg shale seems to be unfossiliferous; the Winterset limestone had yielded lots 426, 645, and 646; the Cherryvale shale lots 162, 164, 167, 193, 194, 210, 216, 217, and 644; the Drum limestone lots 415 and 429; the Chanute shale lots 172, 173, 174, 176, 190, 195, 413, 414, 416, 417, 418, 422, 424, 425, 429a, 656, 681, 683; and the Iola limestone lots 166, 168, 182, 196, 215, 421, 676, 678, 679, 684.

The Kansas City is represented by more numerous collections than any formation except the Cherokee, and by a more varied fauna than any except the Pleasanton. The collections number 47 and they include representatives of nearly 143 species. The fauna is broadly varied as is shown by the presence of protozoans, sponges, corals, crinoids, bryozoans, pelecypods, gastropods, cephalopods, trilobites, and ostracods. The bryozoans are represented by 24 species, the brachiopods by 24, the pelecypods by 27, and the gastropods by 27, the other groups by a few species each. It is noteworthy, however, that the pelecypods and gastropods are found mostly in two collections, deprived of which the fauna would be confined largely to the bryozoans and brachiopods, and would thus present the usual contrast to the Pleasanton fauna in which the molluscan phase predominates.

The two peculiar collections are 426 and 429 which add to the fauna of this formation no less than 17 species, mostly pelecypods and gastropods, not contained in the other collections. One of these lots, 429, is practically all that we have from the Drum limestone in this area, the other Drum collection (415) containing only two species. This fauna is interesting in more ways than one. The fact that it is largely a molluscan fauna has already been pointed out. In this respect it retains its original character, for such is the Drum limestone at Drum, in Kansas. The fauna at Drum is characterized by a robust growth of the varied forms there found. The fauna of lot 429, on the other hand, is a typical dwarf fauna, most of the specimens being diminutive in the extreme. For this reason their identification presents some difficulties, theoretical as well as practical. It has, for instance, seemed best to refer to established species gastropods whose much smaller size, combined with the development of an equal or even greater number of whorls, would ordinarily afford grounds for believing them distinct. The rock at this locality is an oölite, thus answering one of the requirements of the typical dwarf fauna, but the rock at Drum also is oölitic and the fossils robust, which shows that though the conditions under which some oölites were formed were unfavorable to invertebrate species and tended to dwarf their growth, the conditions under which other oölites were formed rather stimulated than retarded such development. I may note also that in general, so far as I recall my personal experience, organic remains abound in oölitic limestones, though they may be worn or fragmentary, and that the faunas are as a rule poor in brachiopods and rich in pelecypods, gastropods, and sometimes in bryozoans.

In connection with lot 429, I should also mention lot 429a which was obtained at a higher horizon in the same section at Kansas City, Missouri. It is not definitely known in what formation this collection was made, whether in the Drum limestone, in the Chanute shale above, or even in the Iola limestone. Lithologically this collection is not a shale but a shaly limestone and it differs from lot 429 in not being oölitic. Corresponding to this lithologic, there is also a faunal difference, the fauna of lot 429a consisting mostly of brachiopods and bryozoans and containing no molluscan types at all. Lot 429a is at present tabulated with the Chanute shale. Its removal from that member to the Drum would make little or no difference in the fauna known from the Chanute, but it would add to the Drum a number of species which our collections (very incomplete be it remembered) do not show from that horizon.

Considered as a whole the fauna of the Kansas City formation appears from the collections at my disposal to be a fauna of corals, crinoids, bryozoans, and brachiopods except for two abnormal collections which introduce a varied pelecypod and gastropod element. The Bryozoa compared with those of lower horizons are numerous and varied. The brachiopods include all the familiar types. Among them *Chonetes verneuilianus* is so persistently present and so abundant that this might appropriately be called the *Chonetes verneuilianus* zone. The fusulinas are likewise abundant for the first time and I find a shifting from the Girtyina[1] type to the Fusulina ss. type. It is true that the fusulinas do occur at lower horizons and that they do not occur in many collections from the Kansas City formation, but in others they are abundant, some hand specimens being thickly covered with them.

Some features in the development of the Pennsylvanian faunas within the Kansas City formation are deserving of mention, such as the coming in of interesting spongoid types related to *Heliospongia ramosa* and *Coelocladia spinosa* and others. They appear in the Chanute shale and Iola limestone and we shall find them recurring at higher horizons. The chief representation of the Bryozoa appears to be in the upper part of the formation, in the Chanute shale and Iola limestone. Peculiarities in range of some of the brachiopod species are shown by the table but their significance, if any, is not understood. As already noted, the molluscan representation is confined largely to two collections and consequently we find these types chiefly in two formations, the Winterset limestone and the Drum limestone. It is interesting to note how little these two faunas have in common. Aside from this, I see little in these molluscan types which calls for further comment. They consist of well-known and for the most part long-ranging species.

The Kansas City fauna contains nearly twice as many species as that of the Pleasanton formation preceding. The number of brachiopods remains about the same, the expansion taking place in the other groups. Among the corals it appears that *Chaetetes milleporaceus* makes its final appearance in the Pleasanton. The crinoids and Bryozoa show a much greater representation in the Kansas City formation but most of the Pleasanton forms occur also in the higher fauna. I note neither final appearances nor first appearances in these groups that may be counted significant. The brachiopods are much the same in both. The predominance of *Chonetes verneuilianus* in the Kansas City formation has already been remarked and with it should also

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[1]This type appears to come in again, however, at higher levels.

be noted the disappearance of the *mesolobus* type of Chonetes, which is so abundant as to characterize the earlier faunas. The occurrence of *Marginifera wabashensis* and *Tegulifera kansasensis* in the Kansas City formation deserves comment; otherwise the Productus group retains its accustomed aspect.

Among the pelecypods the introduction of *Leda arata* (instead of *Leda bellistriata* and *Leda meekana*) and the varied representation of Myalina are interesting features of the Kansas City formation. Other peculiarities may be passed over, attention only being called to the fact that while the pelecypod faunas of these two formations consist of more or less common species they are conspicuously different, though with our still imperfect knowledge of the range of these forms the importance of this difference is hard to estimate.

The Pleasanton fauna is to a considerable extent characterized by its gastropod representation, and that group is much more numerous though represented by much fewer species than it is in the Kansas City formation. This is conspicuously shown in the Bellerophon group, in the Pleurotomarias, and in the Sphaerodomas and Meekospiras (both of which are almost absent from the Kansas City formation). The Kansas City formation, however, shows a better representation along other lines as in Murchisonia, Naticopsis, Zygopleura, and a few other genera.

The Kansas City is the lowest formation of the Missouri group, so that the differences between its fauna and that of the Pleasanton formation, to some extent mark the transition from the Des Moines group to the Missouri group. Some of these have already been noticed. The most striking differences between the faunas of these two groups as exhibited in our collections are the much greater abundance of Fusulina in the Missouri group, and the restriction of Girtyina to the Des Moines group; the restriction of *Chaetetes milleporaceus* to the Des Moines group; the much greater abundance of the Fenestellidae in the Missouri group, and the restriction of Prismopora to the Des Moines group; the restriction of *Rhipidomella pecosi* and *Enteletes hemiplicatus* to the Missouri group and of *Chonetes mesolobus* and its varieties, of *Marginifera muricata, Pugnax rockymontana,* and *Spirifer rockymontanus,* to the Des Moines group; the restriction of the Pterias, Monopterias, Pseudomonatids, Pleurophori and Myalinas, not to mention less conspicuous types, to the Missouri group; the restriction of the scaphopods to the Missouri group, and of numerous species of gastropods to one group or the other. Many other differences are shown by the table and can be readily seen by any one. They are particularly numerous among the gastropods, but many can also be found among the pelecypods. These differences will probably be found much less sweeping in fact, however, than they appear to be in the table, for it is obvious that a species known from but a few specimens at one locality is less characteristic than a species known from hundreds of specimens at a score of localities. The ubiquitous brachiopod, therefore, furnishes more trustworthy evidence than the rarer pelecypod or gastropod. Partly because of their rarity, however, these types appear to be more characteristic, because more restricted in range, than the other, though that appearance no doubt is to an unknown degree deceptive.

TABLE SHOWING RANGE AND DISTRIBUTION OF SPECIES IN THE KANSAS CITY FORMATION.*

Species.	Localities.																																															Hertha limestone member	Bethany Falls limestone member	Winterset limestone member	Cherryvale shale member	Drum limestone member	Chanute shale member.			Iola limestone member
	162	164	166	167	168	172	173	174	176	182	190	193	194	195	196	201	210	215	216	217	233	250	413	414	415	416	417	418	419	421	422	423	424	425	426	429	429a	644	645	646	656	676	678	679	681	683	684						General.	Cement City limestone bed	Raytown limestone bed	
Fusulina secalica?								×																															×	×					×					2			1	1		
Girtyina? sp.																																							×	×										2						
Heliospongia ramosa																																											×	×			×									3
Cœlocladia spinosa											×																																										1			
Somphospongia multiformis?																																										×														1
Axophyllum cylindricum																					×																											1								
Axophyllum infundibulum?																																×																1								
Axophyllum sp. A																																×																1								
Axophyllum sp. B																																×																1								
Axophyllum sp. C																																×																1								
Axophyllum sp. D																																×																1								
Axophyllum sp. E								×																																														1		
Axophyllum sp. F																																					×																1			
Lophophyllum distortum																		×																																						1
Lophophyllum profundum	×		?		×				×					×							×	×																										1	1		1		1	1		2
Campophyllum torquium								×																		×							×				?																1	3		
Monilipora prosseri																																					×																1			
Echinocrinus sp.																					×																											1								1
Hydreionocrinus acanthophorus?					×																																																			
Hydreionocrinus mucrospina																					×																											1								1
Hydreionocrinus sp.			×																																																					
Delocrinus? sp.																					×	×																										1	1								2
Ceriocrinus craigi			×										×					×																																	1					1
Ceriocrinus hemisphericus															×																																									1
Ceriocrinus sp.					?																		×																														1			1
Eupachycrinus magister			×																																																					
Spirorbis carbonaria							×																												×															1					1	
Serpulopsis insita																																						×								×					1				1	
Conularia crustula									×																																?												1		1	1
Fistulipora carbonaria								×		×											×	×															×											1	1				1	1		1
Fistulipora sp.			×				×	×																																						×								1	2	
Cyclotrypa barberi								×						×							×	×															×											1	1				1	1		1
Batostomella greeniana			?																			?																											1							
Batostomella greeniana var. regularis				×													×																			×	×														2	1	1			1
Batostomella polyspinosa	×				?												?																					?													3					
Tabulipora distans																																					?																1			
Tabulipora vera																						×																											1							
Liopora subnodosa																																					×																1			
Chainodictyon laxum																																					×																1			
Fenestella parvipora							×																																																1	
Fenestella tenax																																				×										×						1			1	
Fenestella sp.																																														×									1	
Polypora elliptica							×																		×																											1			1	
Polypora spinulifera							×																																																1	
Polypora ulrichi							×																																																1	
Polypora aff. whitei							×																																																1	
Polypora sp.			×				×																													?	×															1	1		1	1
Septopora biserialis							×																						×																				1						1	
Septopora robusta					×																																																			1
Septopora pinnata			×																																																					1
Pinnatopora sp.							×																																																1	
Rhombopora lepidodendroides					×		?														×					?																						1						1	1	1
Cystodictya? inæquimarginata							?																																																1	
Lingula carbonaria																																			×															1						
Crania modesta?																																														×									1	
Derbya crassa	×					×													×		×	?																×										1	1		3		1			
Derbya crassa var.								×																														×													1			1		
Derbya robusta																								×																															1	
Chonetes verneuilianus	×	×	×	×	×		×					×					×			×	×	×															×	×			×	×						1	1		7		1		2	3
Productus cora	×						×																								?				×															1	1				2	
Productus pertenuis																					×									×																		1								1
Productus semireticulatus																					×	×									×															×		1	1						2	
Productus semireticulatus var.	×							×																																											1			1		
Pustula nebraskensis				×			×	×						×			×		×	×	×									?								×										1			5			2	1	1
Pustula semipunctata										×											×				×																							1				1				1
Pustula symmetrica										×																	×																												1	1
Marginifera splendens	×	×		×				×						×						×	×	×														?	×											1	1		4	1	1	2		
Marginifera wabashensis							×																																																1	
Tegulifera kansasensis																					×																×											1					1			
Dielasma bovidens	×																																			?	×														1	1	1			
Spirifer cameratus					×		×	×									×				×	×									×			×			×											1	1		1		1	1	3	1
Ambocœlia planiconvexa			×																	×	×	×															×	×			×							1	1		2		1		1	1
Squamularia perplexa							×											×																																					1	1
Spiriferina kentuckyensis			×		×		×											×			×	×														?	×									×		1	1			1	1		2	3
Hustedia mormoni			×		×																	×														×													1			1				2
Cliothyridina orbicularis																																				×										×						1		1	1	

Pustula nebraskensis			X			X	X						X			X		X	X	X									?								X												1			5			2	1	1
Pustula semipunctata										X											X				X																											1				1				1
Pustula symmetrica										X																	X																																	1	1
Marginifera splendens	X	X		X				X				X						X	X	X													?	X											1	1		4	1	1	2		
Marginifera wabashensis							X																																																		1	
Tegulifera kansasensis																					X																	X											1					1			
Dielasma bovidens	X																																					?	X														1	1	1			
Spirifer cameratus					X		X	X									X					X	X											X			X			X										1	1		1		1	1	3	1
Ambocoelia planiconvexa			X																			X	X	X																	X	X			X							1	1		2		1		1	1
Squamularia perplexa							X											X																																					1	1
Spiriferina kentuckyensis			X		X		X														X			X	X																?	X										X		1	1			1	1		2	3
Hustedia mormoni			X		X																	X																X														1			1				2
Cliothyridina orbicularis																											X													X											X						1		1	1	
Composita subtilita	X		X		X		X	X							X			X	X						X										X			X	?	X	X								X		1	1	1	3	1	1	2	2	3
Solenomya anodontoides?																																				X														1						
Solenomya parallela																																				X														1						
Clinopistha radiata var. levis																																				X														1						
Edmondia ovata																																				X														1						
Edmondia sp.																																							X											1					
Nucula parva																																					X														1				
Nucula parva var.																																					X														1				
Leda arata																																					?														1				
Leda sp.																							X																												1							
Parallelodon obsoletus?																																					X														1				
Pinna peracuta																	X																																	1							
Conocardium missouriense																																					X														1				
Pteria longa																																					X														1				
Pteria ohioensis																																					X														1				
Bakewellia? sp.																																				X														1						
Pseudomonotis kansasensis							?																												X														1					1	
Myalina aviculoides																																				X														1						
Myalina kansasensis?																																				X														1			1			
Myalina subquadrata						X																																																1			
Schizodus sp.																																					?					X											1			1	
Aviculipecten fasciculatus																																				X														1						
Deltopecten occidentalis?																																		X		X																1			1	
Deltopecten aff. occidentalis																																				X														1						
Deltopecten sp.																																					X														1				
Pleurophorus sp.																																				?	X														1		1				
Cypricardinia carbonaria																																					X														1				
Astartella concentrica																																					?														1				
Levidentalium? sp.																																				X														1						
Bellerophon crassus																																				X														1						
Bellerophon sp.																																					X														1				
Patellostium montfortianum																														X																									1
Euphemus nodicarinatus?																																				X														1						
Bucanopsis bella																																					X														1				
Bucanopsis meekana																														X																									1
Pleurotomaria pratteni?																																					X														1				
Pleurotomaria sp.																																				X	X														1		1				
Murchisonia sp. a																																				X														1						
Murchisonia sp. b																																				X														1						
Murchisonia sp.																		X																																	1					
Phanerotrema grayvillense																																					X														1				
Schizostoma catilloides																																				X														1						
Phymatifer pernodosus?																																				X														1						
Naticopsis? monilifera																																				X														1						
Naticopsis scintilla																																					X														1				
Naticopsis subovata																																				X														1						
Naticopsis sp.																																				X														1						
Loxonema? n. sp.																																					X														1				
Macrocheilina? sp.																																				X														1						
Zygopleura nana																																					X														1				
Zygopleura teres																																					X														1				
Bulimorpha aff. chrysalis																																					X														1				
Bulimorpha minuta																																					X														1				
Soleniscus? sp.																																				X														1						
Aclisina aff. quadricarinata																																					X														1				
Platyceras parvum		X					X																																										1				1	
Orthoceras sp.																																				X														1						
Pseudorthoceras knoxense																				X																															1					
Metacoceras sculptile?																																				X														1						
Domatoceras lasallense?																																				X														1						
Phillipsia major																																				X														1						
Griffithides sp.																																					?	X				X											1	1		1	
Primitia sp.																														X																					1							
Hollina emaciata var. occidentalis?																																							X											1					
Bairdia beedei																																							X											1					
Bairdia sp.																																				X														1						
Cytherella aff. benniei																																							X											1					

*The numbers at the head of the columns indicate localities which are described in the locality register on page 364. The final columns show the faunas found in the different members of the formation, and are composed as follows: Hertha limestone member—comprising lots 233, 423. Ladore shale member—no collections. Bethany Falls limestone member—comprising lots 201, 250, 419. Galesburg shale member—no collections. Winterset limestone member—comprising lots 426, 645, 646. Cherryvale shale member—comprising lots 162, 164, 167, 193, 194, 210, 216, 217, 644. Drum limestone member—comprising lots 415, 429. Chanute shale member (general)—comprising lots 172, 176, 190, 413, 418, 429a(?), 681. Chanute shale member (Cement City bed)—comprising lots 174(?), 195, 416, 424. Chanute shale member (Raytown limestone bed)—including lots 173, 414, 417, 422, 425, 656, 683. Iola limestone member—comprising lots 166, 168, 182, 196, 215, 421, 676, 678, 679, 684. The position of lot 429a is uncertain, though it clearly belongs in the Kansas City formation. It is included among the Chanute shale (general) collections because its position is above the oolitic limestone of lot 429 (Drum limestone), but it may belong with the Drum or even with the Iola. Upon this point the faunal evidence is not clear.

66094—282

LANSING FORMATION.

The Lansing formation includes the Lane shale, the Plattsburg limestone, the Vilas shale, and the Stanton limestone members, from all of which I have collections of fossils. Those from the Lane shale, including the Farley limestone bed, number 14 (163, 171, 189, 275, 285, 285a, 286, 420, 657, 658, 663, 677, 686, and 688); those from the Plattsburg limestone number 9 (185, 280, 295, 296, 659, 680, 682, 685, and 687); the Vilas shale has furnished but one collection (689), and the Stanton limestone 11 (186, 277, 279, 279a, 290, 290a, 305, 306, 690, 691, and 692). In all, my collections from the Lansing formation number 35 and they contain representatives of 114 species. The number of collections, the number of species, and also the number of members in the formation are fewer than in the preceding Kansas City formation.

The interesting group of sponges which were noted in the Kansas City are continued into the Lansing formation and above it. The corals and crinoids are greatly reduced in number in the Lansing, but they are much the same as far as they go. The Bryozoa are likewise fewer in species, the Fenestelloids especially, but here again there are no noteworthy changes. The striking form *Cyclotrypa barberi* is common to both. The Kansas City fauna, as we have seen, was largely a brachiopod fauna except for two collections from different horizons which introduced a varied molluscan element. The Lansing formation also, though not for a similar reason, shows a good development of the molluscan and molluscoidean groups. Both faunas contain the standard brachiopod types but there are some interesting differences. *Rhipidomella pecosi* is abundant in several collections in this formation and above, but I have not found it in the Kansas City formation. *Enteletes hemiplicatus, Derbya bennetti*, and *Meekella striaticostata* are also not found in the Kansas City formation but appear to be introduced in the Lansing. The deeply sinused *Chonetes verneuilianus* begins to be replaced by a form with slightly indented ventral valve which I am calling *C. granulifer*. The Producti show little change from those of the Kansas City formation except that *P. insinuatus* appears among them. Tegulifera, on the other hand, has dropped out. Some of the Marginiferas take on a more strongly costate habit, and such have been distinguished in the table as *M. wabashensis*.

The Lansing formation has 43 species of pelecypods as against 27 in the Kansas City, so that there must of necessity be 16 species in the one fauna not found in the other. In fact the species common to the two faunas are very few. These differences can be seen from the table but the more impressive ones may be mentioned specially. A large Nuculoid which I have identified as *N. anadontoides*? is abundant in several of the collections from the Lansing formation as well as in the following Douglas formation, but it does not apparently occur in the Kansas City formation. *Leda arata*, doubtfully identified in the Kansas City, is here fairly abundant, as it is also in the Douglas formation. The two species of Monopteria are added in the Lansing. The Myalinas, which were a feature of the Kansas City, are further developed in number and variety. The Pectens also add a few species to their number and the Pleurophorus group expands greatly. On the other hand, *Astartella concentrica*, which has been with us for so long, drops out, only to reappear however.

The Lansing formation has fewer gastropods, 18 against 27, and on the whole the complexion of the gastropod element is considerably different. Indeed, it seems to be generally true of these formations that the gastropod representation is less constant than that of any other group.

This may be due to the fact that gastropods are rather rare and that the fauna of the Pennsylvanian comprises in the aggregate a very large number of species, so that most collections, containing but a few of them, are likely to show little community in this type; or it may be that these fossils are in fact highly local in their distribution. There are, nevertheless, a number of species which have a wide distribution and a long range, and can be looked for in almost any carefully made collection east of the Rocky Mountains. Some of these are, however, rare or lacking in the two formational faunas compared. Thus, *Patellostium montfortianum* is not found in the Lansing. *Euphemus carbonarius* has not been found in the Kansas City formation, and is doubtfully present in the Lansing formation. *Phanerotrema grayvillense* also is but rarely and doubtfully present in the Lansing. In this formation, on the other hand, begins the association of *Aclisina quadricarinata* and *Goniospira lasallensis* which occurs frequently in the formation above.

Although the gastropods, cephalopods, and Crustacea do not perhaps show as much difference as, all the circumstances considered, one might expect, the faunal change between the Kansas City and the Lansing formations is one of the most marked in this series of collections and it is well shown in a group in which experience has taught us to look for but little change, the brachiopods.

Considered in their relation to one another the faunas of the Lansing formation require scant comment. Since the Lane shale is well represented in our fossil collections, and also the two limestone members of the formation, we might expect that the fauna of the one would contain most of the Mollusca and would differ from the two others, which would presumably have a predominant brachiopod facies. This proves to be only partly true since the fauna of the Lane shale contains a variety of brachiopods, etc., and the faunas of the Plattsburg and Stanton limestones are not poor in pelecypods and gastropods.

Owing partly, no doubt, to the fact that our knowledge of the fauna of the Vilas shale is almost nil, so that a gap occurs in the paleontologic evidence below the Stanton limestone, a rather strong faunal change is noticed between the Stanton fauna on the one hand and the Lane and Plattsburg faunas on the other hand. This is evidenced by the range of many species shown by the table. A few of these may be mentioned. The Fusulinas are largely confined to the upper fauna. The Fistuliporas occur chiefly in the upper fauna, but the other Bryozoa chiefly in the lower. *Meekella striaticostata* is almost restricted to the upper horizon. *Chonetes granulifer* also is confined to the upper fauna, but *C. verneuilianus* is common to both. *Productus insinuatus* is found only in the lower; so is *Marginifera splendens,* while *M. wabashensis* is restricted to the upper. *Dielasma bovidens, Hustedia mormoni,* and *Cliothyridina orbicularis* are confined to the upper fauna. On the other hand, the Pseudomonotis types are wholly, and the Myalinas largely confined to the lower fauna. Indeed, the chief representation of the pelecypods, and still more of the gastropods is in the lower fauna, but not only do many species of the lower fauna not range into the upper but a considerable percentage of the few gastropods of the upper fauna are not known in the lower.

In the Lane shale itself 9 out of the 14 collections belong to the Farley limestone bed. Lot 275 was obtained below the Farley; the other lots above it. Lot 275 does not possess any special features though its fauna is almost too limited to show any peculiarities that existed. On the other hand a rather marked difference seems to exist between the faunas of the upper and lower parts of the Stanton limestone member. The lower fauna is at least more varied though represented by fewer collections.

TABLE SHOWING RANGE AND DISTRIBUTION OF SPECIES IN THE LANSING FORMATION.*

Species.	Localities.																																			Lane shale member		Plattsburg limestone member	Vilas shale member	Stanton limestone member	
	163	171	185	186	189	275	277	279	279a	280	285	285a	286	290	290a	295	296	305	306	420	657	658	659	663	677	680	682	685	686	687	688	689	690	691	692	Farley limestone bed.	General			Lower part	Upper part
Fusulina sp.							×				×			×	×	×							×											×		1		2		2	3
Heliospongia ramosa																														×			?		?			1			3
Lophophyllum profundum							×							?					×										×							1				1	3
Echinocrinus sp.																																									1
Hydreionocrinus mucrospina																									×											1					
Hydreionocrinus sp.																×																					1				
Spirorbis carbonaria													×				×																				1	1			
Fistulipora carbonaria			×											×																					×			1			3
Fistulipora zonata																																	×								1
Cyclotrypa barberi						?						×																								1	1				
Batostomella polyspinosa	×										×						×								?											2	1	1			
Batostomella greeniana											×	×			×	?					×															3		1		1	
Batostomella greeniana var. regularis	×																							×												1	1				
Tabulipora distans																?	×																					2			
Tabulipora sp.															×																									1	
Polypora sp.												×				×	×					×														2		2			
Septopora biserialis												?					×					×														2		1			
Septopora pinnata											×																									1					
Rhombopora lepidodendroides																		?				×			×									?		2				1	1
Lingula sp.													×																								1				
Rœmerella patula?																									×											1					
Rhipidomella pecosi														×															×							1					1
Enteletes hemiplicatus																×	×																					2			
Derbya bennetti											×				?			×																		1				2	
Derbya crassa	×				×										×		×	×	×							×	×					×					2	3	1	3	
Meekella striaticostata								×	×		×			×																			×	×		1				1	4
Chonetes granulifer				×			×																											×						1	2
Chonetes verneuilianus							×																		×		×									1		1			1
Productus cora							×			×	×				×		?																			1		2		1	1
Productus insinuatus																×	×						?															3			
Productus pertenuis												×			×		×	×															?			1		1		2	1
Productus semireticulatus								×			×	×		×	×	×	×																			2		2		1	2
Pustula nebraskensis					?		×				×	×			×	×	×	×								×										2	1	3		2	1
Pustula semipunctata			×				×								×								×															2		1	1
Pustula symmetrica																	×					?														1		1			

Marginifera splendens											×					×							?													1		2			
Marginifera wabashensis							×							×	×																									1	2
Dielasma bovidens														×	×																									1	1
Spirifer cameratus							×				×			×			×					×									×					3		1			2
Ambocœlia planiconvexa				×							×				×	×		×																		1		1		3	
Squamularia perplexa														×			×																					1			1
Spiriferina kentuckyensis						×								×	×							×														1	1			1	1
Hustedia mormoni							×							×																											2
Cliothyridina orbicularis														×																											1
Composita subtilita	×					×	×			×	×	×		×	×	×	×	×			×	×				×	×		×					×		5	2	5		2	3
Solenomya radiata?																	×																					1			
Sanguinolites costatus?																																		×							1
Edmondia gibbosa?																		×																						1	
Edmondia ovata															×		×																					1		1	
Edmondia sp.												×				×																				1		1			
Nucula anodontoides?					×										×												×										1	1		1	
Nucula beyrichi															×																									1	
Nucula parva													?								×															1	1				
Nucula sp.						×																															1				
Leda arata					×										×		?				×						×									1	1	2		1	
Leda sp.?													×																								1				
Parallelodon obsoletus													×																								1				
Parallelodon sangamonensis															×																									1	
Pinna peracuta												×			×	?		?																		1		1		2	
Bakewellia sp.																?																						1			
Monopteria gibbosa															×																									1	
Monopteria marian																	×																					1			
Pseudomonotis hawni											?						?			×																2		1			
Pseudomonotis kansasensis?																×																						1			
Pseudomonotis sp.																	×																					1			
Myalina ampla																								×												1					
Myalina kansasensis											?	×			×																					2				1	
Myalina perattenuata					×																																1				
Myalina recurvirostris												×																								1					
Myalina subquadrata	×	×			×						×	×				×	×		?	×						×	×						?			3	3	4		1	1
Myalina swallowi											×				×		×				×															2		1		1	
Myalina sp.																																		×							1
Schizodus affinis																	×																					1			
Schizodus ovatus?					×																						×										1	1			
Aviculipecten whitei													×																								1				
Deltopecten coxanus?																								×												1					
Deltopecten mccoyi																					×															1					
Deltopecten occidentalis					?	×					×				×	?	?	?			×															2	2	2		2	
Acanthopecten carboniferus															×																			×						1	1
Streblopteria herzeri?															×																									1	
Modiola subelliptica																×											?											2			
Allerisma terminale							×																																		1
Pleurophorus occidentalis?															×																									1	
Pleurophorus subcostatus					×																						×										1	1			
Pleurophorus taffi?																	×																					1			
Pleurophorus tropidophorus?																					×															1					
Pleurophorus sp.													×																								1				
Cypricardinia carbonaria															×																									1	

TABLE SHOWING RANGE AND DISTRIBUTION OF SPECIES IN THE LANSING FORMATION*—Continued.

Species.	163	171	185	186	189	275	277	279	279a	280	285	285a	286	290	290a	295	296	305	306	420	657	658	659	663	677	680	682	685	686	687	688	689	690	691	692	Lane shale member: Farley limestone bed	Lane shale member: General	Plattsburg limestone member	Vilas shale member	Stanton limestone member: Lower part	Stanton limestone member: Upper part
Bellerophon sp.															×																									1	
Euphemus carbonarius?							×																																		1
Bucanopsis bella					×												×				?						×									1	1	2			
Bucanopsis meekana											?		×																							1	1				
Pleurotomaria brazoensis?															×?																									1	
Pleurotomaria perhumerosa																		×																						2	
Pleurotomaria subconstricta?											×																									1					
Pleurotomaria sp.					×																						×										1	1			
Goniospira lasallensis					×										?						×						×									1	1	1		1	
Phanerotrema grayvillense?																×					×															1		1			
Euconospira bicarinata											×																									1					
Naticopsis altonensis																?	×																					2			
Naticopsis? monilifera					×																						×										1	1			
Zygopleura n. sp.																×	×																					1			
Zygopleura sp.																																						1			
Sphaerodoma primogenia?							×																																		1
Sphaerodoma sp.					×										×?	×																					1	1		1	
Aclisina quadricarinata					×																																1			1	
Nautilus sp.					×																																1				
Metacoceras inconspicuum																×																						1			
Phillipsia major																×	×											×										3			
Phillipsia sp.														×																											1
Primitia sp.													×								?															1	1				
Bairdia beedei																×	×																					2			
Bairdia sp.							×																											×							2
Cytherella sp.												?							×																	1				1	

*The numbers at the head of the columns indicate localities which are described in the locality register on page 361. The final columns show the faunas found in the different members of the formation, and are composed as follows: Lane shale member (general)—comprising lots 163, 171, 189, 275, 286. Lane shale member (Farley limestone bed)—comprising lots 285, 285a, 420, 657, 658, 663, 677, 686, 688. Plattsburg limestone member comprising lots 185, 280, 295, 296, 659, 680, 682, 685, 687. Vilas shale member—comprising lot 689. Stanton limestone member (lower part) comprising lots 186, 279a, 290a, 305, 306. Stanton limestone member (upper part)—comprising lots 277, 279, 290, 690, 691, 692.

DOUGLAS FORMATION.

Our collections from the Douglas formation number 40 and contain representatives of 148 species. The formation consists of four members, between which the collections are distributed as follows: Weston shale 3 (lots 297, 301, 652), Iatan limestone 9 (lots 274, 276, 281, 289, 294, 302, 304, 650, 651), Lawrence shale with the Amazonia limestone bed 12 (lots 205, 207, 208, 213, 276a, 276b, 278, 282, 283, 298, 299, 300), and the Oread limestone 16 (lots 169, 170, 177, 178, 181, 184, 214, 219, 225, 272, 273, 284, 291, 292, 293, 303).

Of the entire series this is perhaps the richest horizon for fossil invertebrates, for, although the number of collections is somewhat fewer than those from the Cherokee shale and Kansas City formation, the total fauna is somewhat larger, while the collections contain more species and more individuals.

Like the Lansing formation which precedes it, the Douglas formation is made up of four members, two shales and two limestones in alternation. The fauna is similarly varied and the number of collections and the number of species are about the same as in the Lansing, five more collections and thirty-four more species being found in the Douglas.

Fusulinas are abundant in this formation as in the other and there are several species. One of them is the form on which my abandoned genus Triticites was based and which I conceive to be typical *F. secalica*, at least as nearly as can now be determined. Besides this there is at least one other species, which may belong to the genus Girtyina. The corals are somewhat better represented in this formation and they are of more unusual types. Of the echinoderms, too, this formation has a somewhat better showing. Bryozoa are more varied but the representation shows no noteworthy departures from those preceding. The brachiopods are sufficiently more numerous to be conspicuous in a group whose differentiation in the Pennsylvanian is small and whose representation is usually large. Practically all the Lansing forms run up into the Douglas formation, the noteworthy exception being *Productus insinuatus*. The chief differences, of course, consist in the introduction of new species in the Douglas fauna. Of these the most interesting are *Chonetes geinitzianus* which is abundant, *Marginifera lasallensis*, and *Tegulifera armata*. The continuation into this fauna from the one below of *Rhipidomella pecosi*, *Enteletes hemiplicatus*, *Meekella striaticostata,* and *Chonetes verneuilianus* is deserving of mention.

In its pelecypods, on the other hand, the Lansing formation excels the Douglas, having 43 species as against 30. In general the pelecypod faunas of the two formations are closely related. The features which they possess in common are in fact more significant than those in which they differ. Among the latter the reintroduction of the Astartellas is perhaps the most peculiar. On the other hand, we note the continuance of *Nucula anadontoides*? and of *Leda arata* in abundance, of Myalina, and of Monopteria.

In the gastropods again the Douglas formation is richer than the Lansing, having 32 species in more or less abundance, while the Lansing has 18 species more or less rare. The slit-bearing forms, the Bellerophons and Pleurotomarias, are particularly strong in this fauna, but they are mostly of the standard Pennsylvanian species. Many of these appear to be missing in the Lansing formation, but it is doubtful if the absence of some of them has any special significance. *Bellerophon stevensianus* appears for the first time and it is abundant. *Orestes intertextus* also is introduced in this fauna and *Trepospira sphærulata* reappears here. *Aclisina quadricarinata* and *Goniospira lasallensis* are abundant as in the preceding formation.

In the Douglas fauna also we find some of the rarer scaphopods. The cephalopods are rather better represented and so far as they go different.

In their relation to one another the faunas of the Douglas formation present features worthy of notice. The most important fact in this connection is that a new fauna comes in with the Oread limestone, or perhaps it would be better to say that a facies different from that of the three other members appears there. This is shown by the fact that the representation of some species is largely, and that of others entirely centered above or below the line that marks the division between the Lawrence shale and the Oread limestone. This is so well shown by the table that only a few species need be mentioned specially. Many whose range appears to be limited by the line dividing the Oread limestone from the Lawrence shale are of minor importance for they merely mark the non-appearance, for some reason, in one formation or the other of species which are found both above and below it. Of these, Fusulinas are an excellent example since they are almost confined to the Oread limestone

(13 out of 14 occurrences being found there), yet the same forms are found both below the Weston shale and above the Oread limestone. *Chonetes geinitzianus*, however, is an instance of another sort since it does not appear earlier, nor indeed later, in the section. Though it is abundant in the lower part of the Douglas formation I have only one occurrence of *Chonetes verneuilianus* in the Oread, nor have I recognized it above.

The peculiarities of the Oread fauna must not be attributed to the contrast frequently observed between shale and limestone faunas, for of the three other members of the Douglas formation one is a limestone and one has a limestone bed, although the mutual agreement is in fact rather greater between the faunas of the two shale members and those of the two limestone members. As already remarked the Fusulinas of this formation occur mostly in the Oread limestone. On the other hand, the most varied representation of the echinoderms is in the Lawrence shale. With a few striking exceptions the chief bryozoan representation again is in the Oread. This is true also of the brachiopods, which are abundant in all four of the members, in the Lawrence shale no less than in the others. The Lawrence shale, however, furnishes almost all the pelecypods, only a scattering representation occurring in the three other horizons. To the Lawrence shale also must we look for the major part of the gastropods, cephalopods, and ostracods, although the Weston shale makes a fair showing. The Iatan and Oread limestones, however, are very poor in those forms.

TABLE SHOWING RANGE AND DISTRIBUTION OF SPECIES IN THE DOUGLAS FORMATION.*

Species.	Localities. 169	170	177	178	181	184	205	207	208	213	214	219	225	272	273	274	276	276a	276b	278	281	282	283	284	289	291	292	293	294	297	298	299	300	301	302	303	304	650	651	652	Weston shale member	Iatan limestone member	Lawrence shale member: Amazonia limestone bed	Lawrence shale member: Lower portion	Oread limestone member
Fusulina secalica											×				×									×		×																			4
Fusulina sp	×			×	×						×	×	×		×									×	×		×															1			9
Endothyra? sp																									×																	1			
Maeandrostria? sp																																		×							1				
Axophyllum cylindricum											×			×																															2
Lophophyllum alleni										×											×													×							1	1	1		
Lophophyllum profundum									×									×		×										×		?		×				×	?		2	2		6	
Lophophyllum distortum										?					×						?																					1	1		1
Campophyllum torquium															?																														1
Echinocrinus dinnini?					×																																								1
Echinocrinus sp															×																×													1	1
Hydreionocrinus acanthophorus																							?		?					×		?					×				1	2		3	
Hydreionocrinus mucrospina									?						×	?				?										?		?		?							2	1		3	1
Ceriocrinus? sp							×					×				×																		×			×				1	2		1	1
Eupachycrinus harei?									×																																			1	
Eupachycrinus tuberculatus?							×																																					1	
Eupachycrinus verrucosus?									×											×																								2	
Eupachycrinus sp																							×							×								×			1	1		1	
Spirorbis carbonaria		×																														×									1			1	1
Serpulopsis insita								×										×	×	×			×							×			×			×		×			2	1		6	1
Fistulipora carbonaria					×																×				×					?				×			×		×		2	4			1
Fistulipora nodulifera		×													×																														2
Fistulipora zonata	×										×			×	×													×																	5
Fistulipora n. sp.															×																														1
Cyclotrypa barberi			×					?							×									?													×					1		1	3
Batostomella polyspinosa		×							×											?				?								?												3	2
Batostomella greeniana		×					×		?				×										×		×											×						1		3	3
Batostomella greeniana var. regularis		×													×																														2
Batostomella sp. A		×																		×											×	?	×											4	1
Tabulipora distans									?																?																	1		1	
Liopora subnodosa															×																														1

Fenestella tenax				×																					×												×					2			1
Fenestella sp.				×																	×								×													2			1
Polypora sp.		×		×	×				×						×						×									×	×	×									1	1		3	4
Septopora biserialis var. nervata		×																																											1
Rhombopora lepidodendroides				×	?				?																		×			?				×	?			?			2	1		2	3
Cystodictya? inaequimarginata																									?																	1			
Crania modesta					×																									×					×			?	×		2	2			1
Rhipidomella pecosi							×		×						×	×		×										?		×	×	×	×	×				×	×		2	3		6	2
Enteletes hemiplicatus	×										×			×	×																														4
Derbya bennetti					×				?					×	×						?						?															1		1	4
Derbya broadheadi															×									×			×	?																	4
Derbya crassa							×		×				×					?	×	×			×										?	×			×	?				1		8	2
Derbya robusta	×	×		×	×				?																						?			×										3	4
Meekella striaticostata															×																														1
Chonetes geinitzianus													×		×									?													×								4
Chonetes granulifer	×		×	×	×	×				×	×	×		×	?												×	?									×						1		12
Chonetes verneuilianus		×					×		×							×		×	×	×	?		×		?					×	×	×	×	×				×	×	×	3	5		9	1
Productus cora			×	×	×	×	×		×					×				×					×				×	×				×	×											6	7
Productus pertenuis							×		?	×										?	×				×				×													3	1	3	
Productus semireticulatus	×		×								×			×	×															×			×				×				1	1		1	5
Productus semireticulatus var.	×			×	×																																								3
Pustula nebraskensis	×	×	×		×				×		×	×	×	×	×									×							×	×	×		×	×						1		4	11
Pustula semipunctata				×											×																														2
Pustula symmetrica			×		×																													×							1				2
Marginifera lasallensis															×																														1
Marginifera splendens																													×	×											1	1			
Marginifera wabashensis			×			×	×		×	×	×			×				×	×								×				×	×	×	×							1		1	7	5
Strophalosia spondyliformis	×																																												1
Strophalosia? sp.																																×												1	
Tegulifera armata															×																														1
Tegulifera kansasensis																					×																					1			
Pugnax osagensis											×				×									×						×											1				3
Dielasma bovidens																×																	×									1		1	
Spirifer cameratus	×	×	×	×	×					×	×	×		×	×	×					×			×			×		×								×					4	1		11
Ambocœlia planiconvexa					×		×		×						×			×		×	×		×							×	×	×	×			×					1	1		8	3
Squamularia perplexa	×		×	×								×		×	×	×		?							?		×	×							×							3			8
Spiriferina kentuckyensis					×		×		×	×					×	×		?			×		×	×						×	×		×	×	×		×		×		2	5	1	6	3
Hustedia mormoni				×							×	×		×	×			×	×	×			×							×		×	×	×					×		2	1		6	5
Cliothyridina orbicularis																×																										1			
Composita subtilita	×	×	×	×	×	×				×	×	×		×	×	×	×		×	×	×		×	×	×		×		×	×	×	×	×	×	×		×	×	×		2	9	1	6	12
Chænomya minnehaha	×																																												1
Edmondia aspinwallensis?						×																																							1
Edmondia ovata																																	×											1	
Edmondia sp.																											×																		1
Nucula anodontoides							?		?									?	×				×							?	?	?	×	?							2			8	
Nuculopsis ventricosa							×	×																																				2	
Leda arata								×	×									×	×				×								×	×	×											8	
Leda meekana							×																																					1	
Yoldia propinqua																														?	?	×									1			2	

TABLE SHOWING RANGE AND DISTRIBUTION OF SPECIES IN THE DOUGLAS FORMATION*—Continued.

Species.	Localities. 169	170	177	178	181	184	205	207	208	213	214	219	225	272	273	274	276	276a	276b	278	281	282	283	284	289	291	292	293	294	297	298	299	300	301	302	303	304	650	651	652	Weston shale member	Iatan limestone member	Lawrence shale member. Amazonia limestone bed	Lawrence shale member. Lower portion.	Oread limestone member
Parallelodon delicatus?									×																																			1	
Parallelodon tenuistriatus?																														×											1				
Parallelodon sp.									×																																			1	
Pinna peracuta	×				×																																								2
Pteria sulcata																									×																	1			
Monopteria marian																												×																	1
Pseudomonotiskansasensis?					×																																								1
Myalina kansasensis									×																																			1	
Myalina recurvirostris?																							×																					1	
Myalina subquadrata									×									×		×		×	×		×						?	?	×			?						1		8	1
Schizodus sp									×																						×		×											3	
Aviculipecten pellucidus?									×																																			1	
Deltopecten occidentalis?			×																						×																	1			1
Deltopecten sp.																															×		×											2	
Acanthopecten carboniferus																														×			×				×				1	1		1	
Modiola subelliptica																							×								×													2	
Allerisma terminale			×		×									×																		?												1	3
Allerisma sp.									×																																			1	
Pleurophorus subcostatus?																																×												1	
Astartella concentrica							×		×									×	×	×			×								×	×	×											9	
Astartella varica																																		×							1				
Dentalium? sp.																		×		×			×										×											4	
Plagioglypta annulistriata																																	×											1	
Clavulites howardensis								×																																				1	
Bellerophon crassus	×													?																															2
Bellerophon stevensianus							×		×											?											×	×	×											6	
Bellerophon sp.															×																														1
Patellostium montfortianum							×		×									×	×	×			×							×	×	×	×								1			9	
Euphemus carbonarius							×	×	×									×	×	×			×							×	×	×	×	×							2			10	
Euphemus nodicarinatus									×																								×											2	
Bucanopsis bella								×	×										×				×								×	×	×											7	
Bucanopsis meekana								×	×									?	×				×								×	×	×											8	
Pharkidinotus percarinatus																														×				?							2				
Pharkidonotus percarinatus var. tricarinatus								×	×										×				×								×	×	×											7	

Pleurotomaria perhumerosa																															X													1	
Pleurotomaria scitula?										X																								X					X		1	1	1		
Pleurotomaria sp.																																		X							1				
Murchisonia sp.																									X																	1			
Goniospira lasallensis							X		X										X				X								X	X	X											7	
Phanerotrema grayvillense							?	X	X										?				X							X	X	X	X	?							2			8	
Euconospira bicarinata?																														X											1				
Orestes intertextus							X		X									X		X			X							X		X	X					?			1	1		6	
Trepospira sphærulata																		X					X							X	X	X	X								1			5	
Schizostoma catilloides									X											X			X							X	X	X	X	X							2			6	
Naticopsis altonensis							?																										X											2	
Naticopsis nana												?																						X							1				1
Naticopsis sp.																											X																		1
Zygopleura rugosa																		X																										1	
Zygopleura sp.																														X											1				
Bulimorpha minuta																									X																	1			
Sphærodoma brevis									X																								X											2	
Sphærodoma intercalaris									?									?	?				?								?	?	X											7	
Sphærodoma sp.								X																X						X											1			1	1
Meekospira peracuta																														X											1				
Aclisina quadricarinata								X											?				X								?	?	X			X								6	1
Platyceras parvum																																		X					X		1	1			
Pseudorthoceras knoxense								X	X										X				X							X	X	X	X	?							2			7	
Metacoceras cavatiforme				?																																									1
Metacoceras hayi?																														X											1				
Metacoceras sp.																																	X											1	
Tainoceras occidentale									X																																			1	
Phillipsia sp.																										X				X			X	X		X					2			1	2
Hollina emaciata var. occidentalis																			X				X								?													3	
Hollina sp.																																X												1	
Bairdia beedei									?									X	X															X		X	X				1	1		3	1
Bairdia sp.																									?					X		X	X	X							2	1		2	
Cytherella benniei									?									?	?												?	X	?			?								6	1
Cytherella sp.																				X																								1	

*The numbers at the head of the columns indicate localities which are described in the locality register on page 364. The final columns show the faunas found in the different members of the formation, and are composed as follows: Weston shale member—comprising lots 297, 301, 652. Iatan limestone member—comprising lots 274, 276, 281, 289, 294, 302, 304, 650, 651. Lawrence shale member (lower portion)—comprising lots 205, 207, 208, 276a, 276b, 278, 282, 283, 298, 299, 300. Lawrence shale member (Amazonia limestone bed)—comprising lot 213. Oread limestone member—comprising lots 169, 170, 177, 178, 181, 184, 214, 219, 225, 272, 273, 284, 291, 292, 293, 303.

SHAWNEE FORMATION.

The Shawnee formation comprises nine members, from only six of which have collections of fossils been obtained, the first, third, eighth, and ninth members being unrepresented paleontologically. The 20 lots from this formation contained in our collections are distributed as follows: Lecompton limestone 5 (lots 183, 222, 224, 227, 288), Deer Creek limestone 3 (lots 165, 191, 229), Calhoun shale 3 (lots 188, 197, 206), Topeka limestone 7 (lots 179, 180, 198, 199, 200, 211, 223), Severy shale 2 (lots 212, 228).

Although the number of members is twice as great as in the Douglas formation the number of collections is only half as many and the number of species is considerably less, only about 100 here as against 148 in the other.

In the Douglas formation the Mollusca were abundantly represented, both in species and in individuals. In this they are relatively rare and the lower organisms predominate. The Fusulinas are still abundant, and as far as determined they belong to the same species as those of the Douglas. The echinoderms show about the same number of species but in that fauna the crinoids, in this the echinoids, are better represented. The echinoid development in these higher horizons of the Carboniferous seems in a measure to be characteristic of them. The Bryozoa of the Shawnee formation are very numerous in species and the fenestelloid types especially show much differentiation. The brachiopods manifest some noteworthy changes. *Enteletes hemiplicatus* appears no more, neither does *Chonetes geinitzianus* nor *C. verneuilianus*. The *splendens* type of Marginifera seems to come in again, while Tegulifera drops out, but otherwise the brachiopod representation remains about the same, in variety at least. The pelecypods are, of course, much fewer, only 15 species having been recognized here, whereas the Douglas fauna contains 30. Of the absentees perhaps the most important are *Nucula anodontoides*, *Leda arata*, Monopteria and Pseudomonotis. On the other hand, the Shawnee fauna contains no introductions of importance.

If the pelecypod representation was small in comparison with that of the Douglas formation, the gastropod representation is still more meager. Only 7 species are recorded while the Douglas contains 32. This shows, of course, a great dying out of species and as the Bellerophons and Pleurotomarias were especially abundant in the Douglas formation, their all but complete absence from the Shawnee is one of the most striking faunal differences between the two formations. *Aclisina quadricarinata* and *Goniospira lasallensis* which have been associated in so many collections do not appear among these of the Shawnee formation. The remaining groups, the cephalopods, trilobites, and ostracods, are poorly represented in both faunas and invite no comment.

Of intrinsic peculiarities the fauna of the Shawnee formation possesses few. The most noteworthy is doubtless connected with lot 206, of whose 9 species only one was found in the other collections. It is this lot, which belongs in the Calhoun shale, that furnished all but one of the gastropods of the Shawnee formation, just as it is the Topeka limestone from which nearly all the pelecypods were obtained. The brachiopods are more generally distributed but the Topeka again furnished most of the Bryozoa and Echinodermata. It should not be forgotten, however, that our collections from this horizon are more numerous than from any other in the formation, and it is this factor and others equally adventitious, as well as the actual abundance of fossils in the beds, that give a color to the apparent facies and relations of faunas.

Of the nine members comprised in this formation three of the shales and one of the limestones are not represented paleontologically. It does not appear that the two shale faunas differ from those of the limestones except that most of the gastropods occur in the Calhoun shale, and we have already seen that their appearance there is due to a single peculiar collection. On the other hand, it was a limestone, the Topeka, that furnished most of the pelecypod forms and although they are conspicuously less abundant than the brachiopods, it may be said of the pelecypods generally that they rarely play more than a subordinate part in our Carboniferous faunas even where best represented.

TABLE SHOWING RANGE AND DISTRIBUTION OF SPECIES IN THE SHAWNEE FORMATION.*

Species.	Localities.																				Lecompton limestone member	Deer Creek limestone member	Calhoun shale member	Topeka limestone member	Severy shale member
	165	179	180	183	188	191	197	198	199	200	206	211	212	222	223	224	227	228	229	288					
Fusulina secalica	×		×	×	×					×		×		×						×	3	1	1	3	
Fusulina sp.	×		×			×						×								×	1	2		2	
Somphospongia multiformis?											×												1		
Lophophyllum alleni						×																1			
Lophophyllum profundum	×		?	×		×							×			×					2	2		1	1
Lophophyllum sp.																				×	1				
Axophyllum? sp. F	×					×																2			
Monilipora prosseri				×																?	2				
Echinocrinus agassizi	×																					1			
Echinocrinus dinnini		×					×			?						×					1		1	2	
Echinocrinus hallanus		×																						1	
Echinocrinus longispina?		×																						1	
Echinocrinus trudifer?		×																						1	
Hydreionocrinus acanthophorus										×														1	
Hydreionocrinus mucrospina		×	×		×		?			×			?			×					1		2	3	1
Ceriocrinus hemisphericus?										×														1	
Ceriocrinus? sp.																×					1				
Serpulopsis insita		×																						1	
Fistulipora carbonaria		×								×														2	
Fistulipora nodulifera			×				?																1	1	
Fistulipora zonata	×										×									×	1	1	1		
Fistulipora sp.												×	×											1	1
Batostomella greeniana		×	×				×					×	×			×		?			1		1	3	2
Batostomella greeniana var. regularis			×																					1	
Batostomella polyspinosa		×	×				×			×													1	3	
Batostomella sp. A	?						×					×										1	1	1	
Tabulipora distans																		×		?	1				1
Tabulipora heteropora?	×																					1			
Fenestella parvipora		×	×				×																1	2	
Fenestella spinulosa			×																					1	
Fenestella tenax	?																			×	1	1			
Fenestella sp.		×																						1	
Polypora crassa	×						?															1	1		
Polypora elliptica		×	×																					2	
Polypora nodicarinata			×																					1	
Polypora spinulifera		×			×		×			×													2	2	
Polypora submarginata			×																					1	

Polypora triangularis?			×																					1	
Polypora ulrichi			?																					1	
Polypora sp.								×									×		×		1	1		1	
Thamniscus cf. divaricans		×																						1	
Thamniscus cf. octonarius		×																						1	
Thamniscus sp.		×																						1	
Septopora biserialis		×	×																					2	
Septopora robusta		×	×																					2	
Rhombopora lepidodendroides		×			×							×	×										1	2	1
Streblotrypa prisca												×												1	
Rhipidomella pecosi																	?			×	2				
Derbya bennetti										?					×									2	
Derbya broadheadi						?	×							?							1	1	1		
Derbya crassa													×												1
Derbya robusta			×																					1	
Meekella striaticostata	×																					1			
Chonetes granulifer	?	×	×		×					×		×	×			×	?			×	3	1	1	4	1
Productus cora														×					×		1	1			
Productus semireticulatus var.	×			×																	1	1			
Pustula nebraskensis	×		×				×	×	×						×	×			×		1	2	1	4	
Pustula semipunctata	×									×												1		1	
Pustula symmetrica?			×																					1	
Marginifera lasallensis?			×																					1	
Marginifera splendens		×	×			×				×		×	×			?					1	1		4	1
Marginifera wabashensis	×																			×	1	1			
Strophalosia spondyliformis		×	×																					2	
Pugnax osagensis																×					1				
Dielasma bovidens	×		×	×						×											1	1		2	
Spirifer cameratus	×	×	×	×	×	×	×			×		×				×				×	3	2	2	4	
Ambocœlia planiconvexa	×												×			×					1	1			1
Ambocœlia lobata				×																	1				
Squamularia perplexa	×													×							1	1			
Spiriferina kentuckyensis	×		×			×				×			×			×					1	2		2	1
Hustedia mormoni	×					×				×			×									2		1	1
Composita subtilita	×	×	×		×	×	×	×	×	×			×			×			×	×	2	3	2	5	1
Edmondia gibbosa?								×							×									2	
Edmondia nebraskensis?								×																1	
Edmondia ovata								×																1	
Edmondia sp.			×																					1	
Myalina kansasensis														×							1				
Myalina subquadrata						×																1			
Myalina sp.															×									1	
Aviculipecten sp.	×																					1			
Pernipecten aviculatus?								×																1	
Deltopecten sp.																			×			1			
Acanthopecten carboniferus?									×															1	
Allerisma granosum									×					?							1			1	
Allerisma terminale									×															1	
Pleurophorus sp.								×																1	
Astartella concentrica											×												1		
Patellostium sp.											×												1		
Pleurotomaria subturbinata?											×												1		
Phanerotroma grayvillense?	×																					1			
Naticopsis sp.											×												1		

TABLE SHOWING RANGE AND DISTRIBUTION OF SPECIES IN THE SHAWNEE FORMATION*—Continued.

Species.	Localities.																				Lecompton limestone member.	Deer Creek limestone member.	Calhoun shale member.	Topeka limestone member.	Severy shale member.
	165.	179.	180.	183.	188.	191.	197.	198.	199.	200.	206.	211.	212.	222.	223.	224.	227.	228.	229.	288.					
Zygopleura nodosa											×												1		
Sphærodoma intercalaris											×												1		
Sphærodoma primogenia											×												1		
Pseudorthoceras knoxense													×												1
Metacoceras? sp.																			×			1			
Phillipsia major				×																	1				
Griffithides scitulus			×											?							1			1	
Jonesina gregaria																		×							1
Cytherella benniei?		×																						1	

*The numbers at the head of the columns indicate localities which are described in the locality register on page 364. The final columns show the faunas found in the different members of the formation as follows: Kanwaka shale member—no collections. Lecompton limestone member—comprising lots 183, 222, 224, 227, 288. Tecumseh shale member—no collections. Deer Creek limestone member—comprising lots 165, 191, 229. Calhoun shale member—comprising lots 188, 197, 206. Topeka limestone member—comprising lots 179, 180, 198, 199, 200, 211, 223. Severy shale member—comprising lots 212, 228. Howard limestone member—no collections. Burlingame shale member—no collections.

WABAUNSEE FORMATION.

The youngest formations of the Carboniferous do not occur in Missouri. The strata above the Shawnee formation all belong to the Wabaunsee formation, only the basal member of which, the Tarkio limestone (probably the same as the Burlingame limestone of Kansas) has been differentiated. The strata above the Tarkio limestone are regarded as probably representing the Willard shale, the Emporia limestone, and the Admire shale of the Kansas Survey.

The collections obtained from the Wabaunsee formation in Missouri are few, and the faunas very small. Thus I have but one collection from the Tarkio limestone (lot 218), none from the Willard (?) shale, two from the Emporia (?) limestone (lots 220 and 226), and one from the Admire (?) shale (lot 221). In all, these collections contain representatives of only 9 species. The scantiness of this fauna is perhaps its most conspicuous feature, but it may also deserve notice that Fusulina continues to be abundant, that the mollusks are entirely absent, and that of the brachiopods, the Producti have not a single representative, a rather unusual thing even in a fauna as meager as this.

TABLE SHOWING RANGE AND DISTRIBUTION OF SPECIES IN THE WABAUNSEE FORMATION.*

Species.	Localities.				Lower limestone (Tarkio limestone member)	Lower shale (Willard?)	Upper limestone (Emporia?)	Upper shale (Admire?)
	218	220	221	226				
Fusulina secalica	×			×	1		1	
Lophophyllum profundum			×					1
Batostomella sp. A			?					1
Rhombopora lepidodendroides				×			1	
Chonetes granulifer		×		×			2	
Pugnax osagensis				×			1	
Pugnax osagensis var. percostata			×					1
Ambocœlia planiconvexa			×					1
Composita subtilita			×	×			1	1

*The numbers at the head of the column indicate localities which are described in the locality register on page 364. The final columns show the faunas found at different horizons in the Wabaunsee and are composed as follows: Lower limestone (Tarkio limestone member)—comprising lot 218. Lower shale (Willard shale?)—no collection. Upper limestone (Emporia limestone)—comprising lots 220, 226. Upper shale (Admire shale?)—comprising lot 221.

TABLE SHOWING THE RANGE OF SPECIES IN THE PENNSYLVANIAN FORMATIONS IN MISSOURI.

Species.	Des Moines Group.			Missouri Group.				
	Cherokee shale	Henrietta formation	Pleasanton formation	Kansas City formation	Lansing formation	Douglas formation	Shawnee formation	Wabaunsee formation
Protozoa—								
Fusulina sp. cf. cylindrica	×							
Fusulina secalica		×	×	?		×	×	×
Fusulina sp.		×			×	×	×	
Girtyina ventricosa	×	×						
Girtyina? sp.				×				
Endothyra? sp.						×		
Porifera—								
Heliospongia ramosa				×	×			
Cœlocladia spinosa?				×				
Mæandrostia? sp.						×		
Somphospongia multiformis?				×			×	
Anthozoa—								
Axophyllum cylindricum		×	×	×		×		
Axophyllum infundibulum				×				
Axophyllum sp. A				×				
Axophyllum sp. B				×				
Axophyllum sp. C				×				
Axophyllum sp. D				×				
Axophyllum sp. E				×				
Axophyllum? sp. F				×			×	
Lophophyllum alleni						×	×	
Lophophyllum distortum				×		×		
Lophophyllum profundum	×	×	×	×	×	×	×	×
Campophyllum torquium	?			×		×		
Amplexus sp.	×							
Monilipora prosseri		×		×			×	
Chætetes milleporaceus	×	×	×					
Vermes—								
Spirorbis carbonaria		×	×	×	×	×		
Serpulopsis insita	×	×	×	×		×	×	
Enchostoma sp.	×							
Conularia crustula				×				
Conodonts	×							
Pelmatozoa—								
Echinocrinus agassizi							×	
Echinocrinus dinnini						?	×	
Echinocrinus hallanus							×	
Echinocrinus longispina?							×	
Echinocrinus trudifer?							×	
Echinocrinus sp.		×		×	×	×		
Hydreionocrinus acanthophorus		×	×	?		×	×	
Hydreionocrinus mucrospina		×	×	×	×	×	×	
Hydreionocrinus sp.				×	×			
Delocrinus? sp.				×				
Ceriocrinus craigi				×				
Ceriocrinus fayettensis?			×					
Ceriocrinus hemisphericus				×			?	
Ceriocrinus? sp.		×		×		×	×	
Eupachycrinus harei?						×		
Eupachycrinus magister				×				
Eupachycrinus tuberculatus	×	×	×			?		
Eupachycrinus verrucosus?						×		
Eupachycrinus sp.						×		
Bryozoa—								
Fistulipora carbonaria	×	×	×	×	×	×	×	
Fistulipora carbonaria var.		×						
Fistulipora nodulifera		×				×	×	
Fistulipora zonata					×	×	×	
Fistulipora sp.	×	×		×			×	
Fistulipora n. sp.						×		
Cyclotrypa barberi				×	×	×		
Batostomella polyspinosa	×	×		×	×	×	×	
Batostomella greeniana	×	×	×	×	×	×	×	
Batostomella greeniana var. regularis				×	×	×	×	
Batostomella sp. A	×	×				×	×	×
Tabulipora distans	×	×		×	×	×	×	
Tabulipora heteropora?							×	

TABLE SHOWING THE RANGE OF SPECIES IN THE PENNSYLVANIAN FORMATIONS IN MISSOURI—Continued.

Species.	Des Moines Group.			Missouri Group.				
	Cherokee shale.	Henrietta formation.	Pleasanton formation.	Kansas City formation.	Lansing formation.	Douglas formation.	Shawnee formation.	Wabaunsee formation.
Bryozoa—Continued.								
Tabulipora aff. ohioensis	×							
Tabulipora vera				×				
Tabulipora sp.		×			×			
Lioclema? sp.		×						
Liopora subnodosa		×		×		×		
Chainodictyon laxum				×				
Fenestella parvipora				×			×	
Fenestella spinulosa							×	
Fenestella tenax		×		×		×	×	
Fenestella sp.	×			×		×	×	
Polypora crassa							×	
Polypora elliptica				×			×	
Polypora nodicarinata							×	
Polypora spinulifera				×			×	
Polypora submarginata							×	
Polypora triangularis?							×	
Polypora ulrichi				×			×	
Polypora aff. whitei				×				
Polypora sp.		×		×	×	×	×	
Thamniscus cf. divaricans							×	
Thamniscus cf. octonarius							×	
Thamniscus sp.							×	
Septopora biserialis				×	×		×	
Septopora biserialis var. nervata						×		
Septopora pinnata				×	×			
Septopora robusta				×			×	
Pinnatopora sp.		×		×				
Rhombopora lepidodendroides	×	×	×	×	×	×	×	×
Streblotrypa prisca							×	
Cystodictya? inæquimarginata				×		?		
Prismopora triangulata	×	×						
Prismopora sp.	×							
Brachiopoda—								
Lingula carbonaria	×			×				
Lingula umbonata	×							
Lingula sp.					×			
Lingulidiscina missouriensis	×							
Roemerella patula?					×			
Crania modesta		×		?		×		
Rhipidomella pecosi					×	×	×	
Enteletes hemiplicatus					×	×		
Derbya bennetti		×	?		×	×	×	
Derbya broadheadi		?				×	×	
Derbya crassa	×	×	×	×	×	×	×	
Derbya crassa var.				×				
Derbya robusta	?			×		×	×	
Orthotetes? sp.		×						
Meekella striaticostata	×	×			×	×	×	
Chonetes geinitzianus			?			×		
Chonetes granulifer	×	×	×		×	×	×	×
Chonetes mesolobus	×	×	×					
Chonetes mesolobus var. decipiens	×	×	×					
Chonetes mesolobus var. euampygus		×						
Chonetes verneuilianus	×	×	×	×	×	×		
Productus cora	×	×	×	×	×	×	×	
Productus costatus?		×						
Productus gallatinensis?	×							
Productus insinuatus					×			
Productus pertenuis	×	×	×	×	×	×		
Productus semireticulatus	×	×	×	×	×	×		
Productus semireticulatus var.				×		×	×	
Pustula nebraskensis	×	×	×	×	×	×	×	
Pustula semipunctata	×	×	×	×	×	×	×	
Pustula symmetrica		×		×	×	×	?	
Marginifera lasallensis						×	?	
Marginifera muricata	×	×						
Marginifera muricata var. missouriensis	×							
Marginifera splendens	×	×	×	×	×	×	×	
Marginifera wabashensis	×	?		×	×	×	×	
Strophalosia spondyliformis		×				×	×	
Strophalosia? sp.						×		

TABLE SHOWING THE RANGE OF SPECIES IN THE PENNSYLVANIAN FORMATIONS IN MISSOURI—Continued.

Species.	Des Moines Group.			Missouri Group.				
	Cherokee shale	Henrietta formation.	Pleasanton formation.	Kansas City formation.	Lansing formation.	Douglas formation.	Shawnee formation.	Wabaunsee formation.
Brachiopoda—Continued.								
Tegulifera armata						×		
Tegulifera kansasensis		×		×		×		
Pugnax osagensis	×	×	×			×	×	×
Pugnax osagensis var. percostata	×							×
Pugnax rockymontana	×							
Cryptacanthia compacta		×						
Dielasma bovidens		×		×	×	×	×	
Spirifer cameratus	×	×	×	×	×	×	×	
Spirifer rockymontanus	×							
Ambocœlia lobata							×	
Ambocœlia planiconvexa	×	×	×	×	×	×	×	×
Squamularia perplexa	×	×	×	×	×	×	×	
Spiriferina kentuckyensis	×	×	×	×	×	×	×	
Hustedia mormoni	×	×	×	×	×	×	×	
Cliothyridina orbicularis	×	×	×	×	×	×		
Composita subtilita	×	×	×	×	×	×	×	×
Pelecypoda—								
Solenomya anodontoides?				×				
Solenomya parallela				×				
Solenomya radiata?					×			
Solenomya soleniformis	×							
Solenomya trapezoides	×							
Sanguinolites costatus		×			?			
Clinopistha radiata var. levis		×		×				
Chænomya minnehaha						×		
Cardiomorpha missouriensis	×	×						
Edmondia aspinwallensis?						×		
Edmondia gibbosa?	×				×		×	
Edmondia glabra?			×					
Edmondia nebraskensis?							×	
Edmondia ovata			×	×	×	×	×	
Edmondia reflexa?			×					
Edmondia sp.	×		×	×	×	×	×	
Nucula anodontoides			×		?	×		
Nucula beyrichi					×			
Nucula parva	?			×	×			
Nucula parva var.				×				
Nucula sp.			×		×			
Nuculopsis ventricosa	?		?			×		
Leda arata		×		×	×	×		
Leda meekana			×			×		
Leda sp.				×	?			
Yoldia propinqua						×		
Parallelodon delicatus?						×		
Parallelodon obsoletus				?	×			
Parallelodon sangamonensis					×			
Parallelodon tenuistriatus?	×					×		
Parallelodon sp.			×			×		
Pinna peracuta				×	×	×		
Conocardium missouriense				×				
Pteria longa				×				
Pteria ohioensis				×				
Pteria sulcata	?					×		
Bakewellia? sp.				×	×			
Monopteria gibbosa					×			
Monopteria marian					×	×		
Pseudomonotis hawni					×			
Pseudomonotis kansasensis				×	?	?		
Pseudomonotis sp.					×			
Myalina ampla					×			
Myalina aviculoides				×				
Myalina kansasensis				?	×	×	×	
Myalina perattenuata					×			
Myalina perniformis?	×							
Myalina recurvirostris					×	?		
Myalina subquadrata				×	×	×	×	
Myalina swallowi	?				×			
Myalina sp.					×		×	
Schizodus affinis					×			
Schizodus ovatus?					×			
Schizodus rossicus?			×					

TABLE SHOWING THE RANGE OF SPECIES IN THE PENNSYLVANIAN FORMATIONS IN MISSOURI—Continued.

Species.	Des Moines Group.			Missouri Group.				
	Cherokee shale	Henrietta formation	Pleasanton formation	Kansas City formation	Lansing formation	Douglas formation	Shawnee formation	Wabaunsee formation
Pelecypoda—Continued.								
Schizodus sp.				×		×		
Aviculipecten fasciculatus				×				
Aviculipecten pellucidus	×					?		
Aviculipecten aff. pellucidus			×					
Aviculipecten rectilaterarius	×							
Aviculipecten aff. rectilaterarius	×							
Aviculipecten whitei	×				×			
Aviculipecten sp.	×	×					×	
Pernipecten aviculatus	×		×				?	
Deltopecten coxanus?					×			
Deltopecten mccoyi					×			
Deltopecten occidentalis				?	×	?		
Deltopecten aff. occidentalis				×				
Deltopecten sp.				×		×	×	
Acanthopecten carboniferus	×		?		×	×	?	
Euchondria neglecta	×							
Streblopteria herzeri?					×			
Lima gregaria	?	×						
Lima retifera	×							
Placunopsis recticardinalis	×							
Modiola subelliptica					×	×		
Allerisma granosum							×	
Allerisma terminale	×	×			×	×	×	
Allerisma sp.						×		
Pleurophorus occidentalis?					×			
Pleurophorus subcostatus					×	?		
Pleurophorus taffi?					×			
Pleurophorus tropidophorus?					×			
Pleurophorus sp.				×	×		×	
Cypricardina carbonaria				×	×			
Astartella compacta	×							
Astartella concentrica	×		×	×		×	×	
Astartella varica						×		
Astartella sp.	×							
Scaphopoda—								
Dentalium? sp.						×		
Levidentalium? sp.				×				
Plagioglypta annulistriata						×		
Clavulites howardensis						×		
Gastropoda—								
Bellerophon crassus				×		×		
Bellerophon crassus var. wewokanus?			×					
Bellerophon stevensianus						×		
Bellerophon sp.				×	×	×		
Patellostium montfortianum	×		×	×		×		
Patellostium sp.							×	
Euphemus carbonarius	×	×	×		?	×		
Euphemus nodicarinatus				?		×		
Bucanopsis bella		×		×	×	×		
Bucanopsis meekana			×	×	×	×		
Pharkidonotus percarinatus	×		×			×		
Pharkidonotus percarinatus var. tricarinatus						×		
Pleurotomaria brazoensis?					×			
Pleurotomaria perhumerosa					×	×		
Pleurotomaria persimplex	×							
Pleurotomaria pratteni?				×				
Pleurotomaria scitula?						×		
Pleurotomaria subconstricta?					×			
Pleurotomaria subturbinata?							×	
Pleurotomaria sp.		×		×	×	×		
Murchisonia missouriensis	×							
Murchisonia sp. a				×				
Murchisonia sp. b				×				
Murchisonia sp.			×	×		×		
Goniospira lasallensis					×	×		
Phanerotrema grayvillense	×	×	×	×	?	×	?	
Euconospira bicarinata?					×	×		
Orestes intertextus						×		
Orestes nodosus			×					
Trepospira depressa	×							

TABLE SHOWING THE RANGE OF SPECIES IN THE PENNSYLVANIAN FORMATIONS IN MISSOURI—Continued.

Species.	Des Moines Group.			Missouri Group.				
	Cherokee shale.	Henrietta formation.	Pleasanton formation.	Kansas City formation.	Lansing formation.	Douglas formation.	Shawnee formation.	Wabaunsee formation.
Gastropoda—Continued.								
Trepospira sphærulata	?		×			×		
Schizostoma catilloides	×		×	×		×		
Phymatifer pernodosus?				×				
Naticopsis altonensis	×		×		×	×		
Naticopsis? monilifera				×	×			
Naticopsis nana	×					×		
Naticopsis scintilla				×				
Naticopsis subovata				×				
Naticopsis sp.				×		×	×	
Naticella americana	×							
Loxonema? n. sp.				×				
Macrocheilina? sp.				×				
Zygopleura affinis	×							
Zygopleura multicostata	×							
Zygopleura nana				×				
Zygopleura nodosa							×	
Zygopleura parva?	×							
Zygopleura plicata	×							
Zygopleura rugosa						×		
Zygopleura teres				×				
Zygopleura n. sp.					×			
Zygopleura sp.	×	×			×	×		
Hemizyga dubia	×							
Hemizyga elegans	×							
Hemizyga grandicostata	×							
Bulimorpha chrysalis	×			?				
Bulimorpha inornata	×							
Bulimorpha minuta	×			×		×		
Bulimorpha? sp.	×							
Sphærodoma brevis			×			×		
Sphærodoma? fusiformis	×							
Sphærodoma gracilis?	×							
Sphærodoma intercalaris			×			×	×	
Sphærodoma primogenia			×		?		×	
Sphærodoma ventricosa?			×					
Sphærodoma sp.	×		×		×	×		
Meekospira peracuta	×		×			×		
Meekospira? sp.	×		×					
Soleniscus? sp.				×				
Aclisina quadricarinata		×			×	×		
Aclisina n. sp. aff. quadricarinata				×				
Aclisina stevensana?		×						
Aclisina? sp.	×							
Trachydomia wheeleri	×							
Platyceras parvum				×		×		
Cephalopoda—								
Orthoceras sp.	×	×		×				
Pseudorthoceras knoxense	×		×	×		×	×	
Nautilus sp.	×				×			
Metacoceras cavatiforme						×		
Metacoceras aff. cornutum	×							
Metacoceras hayi?						×		
Metacoceras inconspicuum					×			
Metacoceras sculptile?				×				
Metacoceras sp.						×	×	
Tainoceras occidentale						×		
Domatoceras lasallense?				×				
Milleroceras parrishi?		×						
Gastrioceras welleri	?	×						
Goniatites sp.	×		×					
Trilobita—								
Phillipsia major		?	×	×	×		×	
Phillipsia sp.					×	×		
Griffithides scitulus							×	
Griffithides sp.			×	×				
Ostracoda—								
Primitia sp.	?			×	×			
Hollina emaciata var. occidentalis				?		×		
Hollina sp.	×					×		

TABLE SHOWING THE RANGE OF SPECIES IN THE PENNSYLVANIAN FORMATIONS IN MISSOURI—Continued.

Species.	Des Moines Group.			Missouri Group.				
	Cherokee shale....	Henrietta formation..	Pleasanton formation..	Kansas City formation..	Lansing formation..	Douglas formation..	Shawnee formation..	Wabaunsee formation..
Ostracoda—Continued.								
Jonesina gregaria	....	....	....	....	....	....	×	....
Kirkbya centronata	....	....	×	....	....	....	....	....
Bairdia beedei	....	....	×	×	×	×	....	....
Bairdia aff. beedei	....	×	....	....	....	....	....	....
Bairdia sp.	×	×	×	×	×	×	....	....
Cytherella benniei	....	....	....	....	....	×	?	....
Cytherella aff. benniei	....	....	....	×	....	....	....	....
Cytherella sp.	×	×	×	....	×	×	....	....

DESCRIPTION OF SPECIES.

Genus Axophyllum Milne-Edwards and Haime.

The original diagnosis of this genus was very brief, stating merely that the corallum was simple, trochoid, and similar to Lithostrotion in its structure, the latter name being reserved for composite, fasciculate, or astraeiform colonies. It must also be borne in mind that at the time this diagnosis was published the name Lithostrotion was associated with the structure now known as the genus Lonsdaleia. A year later a more elaborate description was given in French, of which the following is a translation. Corallum simple, turbinate, surrounded by a complete epitheca. The zone adjacent to the epitheca sub-vesicular; internal wall well marked; septa well developed; columella very large, cylindrical and formed of twisted plates. This genus differs from Lonsdaleia in being always simple. For the rest it presents the same structure except that the septa are better developed and almost lamellar.

The type of Axophyllum is stated in the original description to be *A. expansum*, which was figured by the authors, Milne-Edwards and Haime, in 1851. Their figures, however, show only the exterior of the coral and for any representation of the internal structures of Axophyllum we must look to another species, *A. radicatum*. We notice that in *A. expansum* there is a large central axis which in the calice is not connected with any of the septa. The septa themselves are alternately long and short and extend from the pseudo-columella to the epitheca.

The structure of *A. radicatum* as seen in the figure which represents a longitudinal section, consists of a thick pseudo-columella constructed of arched plates inclined to each other on opposite sides of an imaginary axis at an acute angle. There is a peripheral zone composed of similar arched plates in cystose structure, only here the plates are larger, thicker and opposite in direction, being directed obliquely inward from above, whereas those of the pseudo-columella are directed obliquely outward from above. The overlapping edges of these plates are in adjustment so as to form fairly regular walls around the peripheral zone and around the pseudo-columella between which is an intermediate zone that is distinguished by having the tabulae or plates much fewer, more nearly flat, and more nearly horizontal. In this and in a third species refered to Axophyllum the septa are represented as beginning at the epitheca and reaching to or nearly to the pseudo-columella.

I have made special mention of the length of the septa in Milne-Edwards and Haime's figures because there seems to be a discrepancy between their description and their specimens. In Lonsdaleia, as is well known, the epitheca is surrounded by a zone of vesicles which is not penetrated by the septa. The septa consequently are restricted to an intermediate zone reaching neither to the center nor to the periphery. Of course, if Axophyllum has the structure of Lonsdaleia and is distinguished only by comprising simple instead of composite corals, the same structure should be found in Axophyllum. Just how this structure would be expressed externally in the calice no one can predict but it is safe to say that the appearance would not be that represented by Milne-Edwards and Haime's figures, which can only represent corals in which the septa begin at the epitheca.

This distinction appears to be an important one and the question arises to which type of structure does the generic term especially apply, or were, perhaps, both types included in Axophyllum by the authors of the genus. A suggestion that both types were included is found in a statement made in the later publication that Axophyllum presents the same structures as Lonsdaleia, except perhaps that the septa are better developed and almost lamellar.

The statement found in some works that Axophyllum has an outer vesicular zone, is probably intended to describe the structure of Lonsdaleia but it is ambiguous because in longitudinal section both types of structure show an outer vesicular zone and it is only in transverse sections that the expression quoted has real significance, for in such sections the one type of structure shows a peripheral zone that is vesicular only, while the other type shows a peripheral zone which is vesicular but is also traversed by septa.

My specimens from Missouri show in fact both types of structure, but the type which has the septa continued to the epitheca is much more abundant. It is represented by *Axopyllum cylindricum;* the other by *Axophyllum? sp. D.* The occurrence of these two distinct though related types of structure in the same beds has raised the questions whether they should be regarded as exemplifying two genera or merely two different modifications of one genus, and if they exemplify two genera for which should the name Axophyllum be retained. For the present, both types of structure are included in one genus and, of course, the name Axophyllum is used for it.

My specimens also show a certain structure not mentioned by Milne-Edwards and Haime, nor by other authors, and it is somewhat doubtfully present in typical Axophyllum. That is, the pseudo-columella is normally connected by its ends with two opposite septa and is traversed by a median plate continuous with those septa, thus showing bilateral symmetry in the most conspicuous manner. A similar arrangement may be observed in typical Lonsdaleia and thus it is in a way implied in Milne-Edwards and Haime's description of the genus Axophyllum. On the other hand, it is not shown by their figures, though it would hardly be as apparent in the calice as in sections and might easily have been overlooked in drawing the specimen even if actually present. In addition to the transverse plate there are in my specimens other radial plates but these would hardly appear in the calice since they are not connected with the septa.

Certain other modifications of structure found in my corals have been difficult to interpret in their generic bearing. The most important of these modifications is characterized by the presence of a solid instead of a vesicular axis which furthermore appears to be connected with only one septum instead of with two opposite septa. The axis, even though solid, show similar radial structure. Aside from the axis the structure of this type is like Axoplyllum, e.g., *A. cylindricum.* That is, there is an outer zone made up of oblique cysts whose closely adjusted edges form a sharply defined wall, and an intermediate zone partitioned by more nearly complete flat and horizontal tabulae. It is a singular fact that, in the presence of a peripheral cystose zone which is not traversed by the septa the same structural modification is found among the specimens having a solid axis as in the forms having an axis composed of twisted plates. Some specimens have such a vesicular zone and others do not.

Still another modification of the same structure is presented by one specimen in which most of the characters are the same as those of *Axophyllum cylindricum.* The central area, however, instead of being occupied by very oblique plates that form a complex pseudo-columella, is crossed only by gently arching plates or tabulae that form only a low boss instead of a pillar rising from the center of the calice.

The type with solid columella at once suggests the genus Lophophyllum but all the other structures are different from those of Lophophyllum, which possesses very little dissepimental tissue. Still less is this tissue so disposed as to form three zones of which the outer is bounded by an inner wall. Rather than refer such forms to Lophophyllum I would introduce a new genus, for no described genus with which I am acquainted can properly include them. On the other hand, it is at least plausible that these two types which might be called distinct genera are really only modifications of the Axophyllum structure. It is easy to conceive of the pseudo-columella of typical Axophyllum as narrowed down so that the plates instead of leaving spaces between them were in contact and formed a solid axis in which, however, the radial structure was still retained. On the other hand, the plates composing the pseudo-columella can be thought of as being directed at less and less acute angles to one another until the pseudo-columella instead of projecting like a central pillar was flattened to a low boss and the plates themselves became almost tabulae. The occurrence of these extreme structures in the same beds and almost at the same locality leads the observer to think that they may be modifications of the same structure. On the other hand, the fact that complete intermediate stages have not been found even though the size and distinctness of the pseudo-columella does vary greatly in *A. cylindricum* tends to foster the belief that although these different types may theoretically be modifications of the same assemblage of structures, they are too different and too distinct to be held within a single genus.

My own observations and my own material are hardly complete enough to decide the questions raised by them or to warrant the introduction of new generic names and consequently I am citing all these forms under the genus Axophyllum, but with a large element of uncertainty.

There are, then, two if not three types of structure included here, of which only that having a large vesicular pseudo-columella belongs with any certainty to Axophyllum. This group comprises *A. rude, A. infundibulum, A. cylindricum* and *Axophyllum sp. D*, and of these *A. infundibulum* and *Axophyllum sp. D*, are possibly also distinct by reason of the more or less obsolete pseudo-columella. The second group has the pseudo-columella apparently solid and includes *Axophyllum sp. A*, *Axophyllum sp. B*, *Axophyllum sp. C*, *Axophyllum sp. E*, and *Axophyllum sp. F*. This group may be an entirely distinct genus, but it is not Lophophyllum which it resembles in the solid pseudo-columella. Both groups contain forms in which the septa are not complete, but are prevented by an external layer of vesicular tissue from connecting with the epitheca.

Axophyllum cylindricum n. sp.

Corallum simple, gradually tapering or subcylindrical; nearly straight, or irregular marked by the usual annular constrictions and growth lines, neither of them very pronounced. Diameter 15 mm. or less. There are more or less distinct longitudinal striae produced by the septa. The primary septa are 25 to 27 with an equal number of secondary septa. A small fossula is present in some specimens, but in others is not distinct.

In transverse section the primary septa are seen to extend rather more than one-half the distance to the center. They are not all of equal length but no order of arrangement is observable. They are more or less thickened in the median portion but thin toward the center and less conspicuously toward the epitheca. Much variation is shown in this respect. The secondary septa where present are about half the length of the primary septa but the interseptal loculi are not always provided with them. In one specimen they seem to be wanting on one side of the corallum.

The median portion is occupied by the rather large pseudo-columella which, as seen in the transverse sections that are now under consideration, has a spider-web pattern, being composed of radial and concentric lines. The radial elements may be considered continuations of the septa but they are much fewer than the septa and their number is not constant (from 6 to 10). The most striking feature of the pseudo-columella is that one of these plates, more conspicuous than the rest, passes from side to side of the pseudo-columella, while the others, though directed obliquely to it, are not strictly radial in direction and do not meet at a point. This structure indicates strong bilateral symmetry.

Between the axial zone formed by the pseudo-columella, and the peripheral zone, both of which are fairly well defined, is an intermediate zone combining to some extent the characters of the two. Some of the septa traverse this zone in a very attenuated condition. There are also the edges of transverse plates, appearing as concentric lines, but these are thinner and more widely spaced than those of which the pseudo-columella is formed.

The peripheral zone is about one-half a radius in thickness and is distinguished by a great amount of interseptal tissue.

In longitudinal section the peripheral zone is seen to be composed of innumerable oblique curved plates giving this region a finely cystose structure. The plates have their convex side uppermost and are strongly oblique from the epitheca downward. The central or pseudo-columellar region, on the other hand, has the plates much longer and straighter, and very oblique upwards to the axis. The intermediate zone has the plates less numerous, more regular, nearly flat and horizontal. The three zones are more or less clearly defined by what appear to be walls but the walls are composite and are formed by the terminal portions of the oblique plates in approximate adjustment. This is at least true of the outer zone; the boundary between the intermediate and axial zones is apt to be indistinct, the series of horizontal plates of the one merging with the series of oblique plates of the other without a definite boundary.

In the present unsettled condition of coral genera it is necessary in determining specific relationships to consider, more than usual, forms which at present appear under different generic assignments. The species whose description is given above is clearly not one of the more common Pennsylvanian types. A species related to this would more probably find place under the genus Axophyllum than under Lophophyllum. Indeed, I can not entirely satisfy myself that this is not our well-known (?) *Axophyllum rude* which was so poorly described that we do not even now know how many septa it possessed, nor other characters equally fundamental. *Axophyllum rude* is always represented as having a more spreading growth and I think it must be distinct from this species.

More similar to *A. cylindricum* in its cylindrical shape is Worthen's *Axophyllum infundibulum.* Here again the diagnosis is extremely inadequate; most of the characters given might be applied to almost any Zaphrentoid coral. The size of *A. infundibulum* is considerably larger than that of this species and the peculiar growth, if it be regarded as more than an individual or possibly a pathologic character, would be another difference between them. Worthen does state that the septa number about 40 but fails to record whether they are all primary. In *D. cylindricum* the total number is very near 50 and the number of primary septa is only 27. Again, Worthen states that the columella (pseudo-columella) is not strongly developed which is far from true of my species. On the whole, I am forced to conclude that this is not *A. infundibulum.* Indeed, Worthen's figure rather suggests to me the genus Craterophyllum.

The specimens referred to *A. cylindricum* show much variation. The description given above is based largely upon the type specimens and it will be desirable to note some of the departures from it. Few specimens exceed a length of 30 mm. and a diameter of 15 mm.; some long and nearly cylindrical specimens, however, have a diameter of only 7 mm. Several rather large specimens from locality 423 have 32 or 33 septa. Secondary septa are usually present but in a few specimens they are absent in part or wholly. A fossula appears to be present in some specimens but absent in others. Possibly the structure is really absent but appears to be present in some specimens owing to the unequal length of the septa as already mentioned. The pseudo-columella varies from small to large and, as seen in cross sections, from a closely arranged aggregation of plates with definite boundaries to a group of dispersed and less numerous plates which scarcely appear to form a pseudo-columella at all. Usually the pseudo-columella is conspicuously connected with two opposite septa and divided by a median plate which appears to be a continuation of those septa. This structure may be indistinct, however, and when the pseudo-columella itself almost loses identity, the accompanying structures are scarcely appreciable. In longitudinal section the intermediate zone is sometimes distinct and made up of nearly flat, fairly remote, transverse plates, but it is sometimes more or less fused with the axial zone, the plates being more numerous, more oblique, and intercalated with those of the central portion. The septa are usually appreciably thickened in the median portion, thinning toward the center and toward the epitheca. In some specimens the thickening begins at the epitheca, and in one specimen particularly the septa are thin throughout the peripheral zone, but are abruptly thickened where they enter the intermediate zone, thinning regularly toward the pseudo-columella.

Horizon and locality: Henrietta formation—Pawnee limestone member, station 1255 B3. Pleasanton formation, stations 430, 647, 672. Kansas City formation—Hertha limestone member, station 233. Douglas formation—Oread limestone member, stations 214, 272.

Axophyllum infundibulum Worthen?

1875. *Axophyllum infundibulum.* Worthen, Geol. Surv. Illinois, Rept., vol. 6, p. 525, pl. 32, fig. 7.
Coal Measures: Clark County, Ill.

This type also is represented by a single specimen, a nearly straight, rapidly enlarging Zaphrentoid coral having a diameter of about 23 millimeters and a length of about 30 millimeters. The calice is shallow, the edges of the septa arching and descending obliquely toward the center, where a small circular pit is formed, 6 millimeters in diameter, with a slightly up-arched bottom, onto which the septa extend as narrow ridges. The septa number 31 and are all primary. Twelve millimeters from the top the structure of this coral in cross section is as follows: The septa, 28 in number, reach from the epitheca to a central area which has a diameter of 6 millimeters or less. This large, ill-defined columellar area is crossed by the irregular continuations of some of the septa and by a number of concentric lines representing the edges of transverse plates. It is surrounded by a narrow intermediate zone in which, in this section, no tabular structures appear. Outside of this intermediate zone comes the broad peripheral zone characterized by fine, interseptal tissue. These interseptal plates have the appearance of springing from the sides of the septa and being carried part way, or wholly, across the interseptal loculi and meeting obliquely and interrupting similar plates springing from the adjacent septa. This gives the interseptal tissue an irregular arrangement and the septa themselves seem to be more or less disturbed in direction, and in size.

In longitudinal section the peripheral zone is composed of small, oblique cysts and has well defined boundaries. A series of thinner, larger, less convex plates occupies the area between. Though each is much shorter than the entire width of this area and though they overlap one upon the other, they make broadly convex lines which dome upward in the center and descend at the sides. The area of the pseudo-columella is distinguished less by changes in the number and direction of the plates than by thickened lines (ends of septa?).

In general structure this specimen agrees with those called *Axophyllum cylindricum*, the chief difference being in the distinctness of the pseudo-columella in which even that species varies considerably. In typical examples of *A. cylindricum* the pseudo-columella is smaller and more sharply defined by reason of its more numerous and more closely arranged plates, and the greater width of the intermediate zone. It is also conspicuously connected with two of the septa but is not traversed by others of them. It has a transverse plate and also radial plates which in the present form are either absent or only suggested. Other characters distinguish the two forms specifically but for the present no marked objection is seen to including both in one genus. The identification with *Axophyllum infundibulum* is made on the strength of a statement in the original description that the columella is nearly obsolete in some examples and much less strongly defined than in *A. rude*. On the other hand, the septa in *A. infundibulum* are said to number 40, distinctly more than in the present form, and the peculiar growth of the typical specimen, if regarded as a specific character, distinguishes it.

Horizon and locality: Kansas City formation—Hertha limestone member, station 423.

Axophyllum rude White and St. John.

1868. *Axophyllum rudis.* White and St. John, Chicago Acad. Sci., Trans., vol. 1, p. 115.
Upper Coal Measures: Madison, Ringgold, and Pottawattamie counties, Iowa.

1875. *Axophyllum rudis.* Meek and Worthen, Geol. Surv. Illinois, Rept., vol. 6, p. 525, pl. 32, figs. 6a-c.
Coal Measures: Near Collinsville, St. Clair County, Ill.

1884. *Axophyllum rudis.* White, Dept. Geol. Nat. Hist. Indiana, 13th Ann. Rept. pt. 2, p. 118, pl. 23, figs. 8, 9.
Coal Measures: Newport, Ind.

1894. *Axophyllum rude.* Keyes, Missouri Geol. Surv., Rept., vol. 4, p. 107, pl. 12, figs. 5a, b.

Upper Coal Measures: Kansas City, Mo.

1900. *Axophyllum rudis.* Beede, Univ. Geol. Surv. Kansas, Rept., vol. 6, p. 20, pl. 2, figs. 9-9c.

Upper Coal Measures: Kansas City and Lawrence, and Osage, Cowley, and Elk counties, Kans.

The status of this species is unsatisfactory in the extreme. When the name was introduced in 1868 White and St. John gave no figures and the description, dealing only with external characters, would apply to almost any simple Paleozoic coral. Not a single really diagnostic specific character was set down.

Meek and Worthen cited the species in 1875 and figured two specimens from Illinois. They merely quoted the original description, remarking that their specimens (naturally) agreed with the characters given. Their figures add but little to the nearly blank page of our knowledge of the species; they do not show for instance, whether the septa are of one or of two orders nor what the number of them is. Knowing already that the species probably has both primary and secondary septa, I interpret their figures as showing 28 or 30 of the one order and a few of the other.

White returned to *A. rude* in 1889 and we may assume that since he was one of the original authors his identification is correct. He seems to be content with the original diagnosis which he paraphrases. He does give two figures which represent a coral 20 mm. in length and 12 mm. in diameter. This is only about half the size of the specimen figured by Meek and Worthen. One figure shows about 40 septa but it is not clear whether they are of one or two orders. I suspect that a few are secondary, but that all the rest are primary.

The next author to treat of *A. rude* was Keyes, who figures the species but does not describe it. His figures depict a form very similar to White's Indiana specimen. One of his illustrations shows 31 septa, several of which are distinctly shorter than the others (secondary?). Very short, undeveloped intermediate septa are also shown.

The latest discussion of the species is by J. W. Beede to whom we owe about everything essential that is known of it. The only question, of course, is whether his specimens are actually *A. rude* or some other species. His description is less enlightening than his figures. He describes the external characters much as preceding writers had described them. He states that the septa are of two orders, but does not give their number. His figures, of which there are three, include one thin section showing the structure. The two other figures represent a small coral generally similar to the figures of White and of Keyes.

The cross section represents the septa as of two orders, the primary septa reaching to or nearly to the pseudo-columella, the secondary septa about half as long, some more, some less. Each set comprises 26; 52 in all. The illustration shows an outer vesicular zone and an inner vesicular zone (the pseudo-columella) separated by an intermediate zone which is traversed only by the septa. Probably the intermediate zone, instead of being represented as entirely destitute of interseptal or tabular structures, would more correctly be shown as possessing them, though to a less degree than the two other regions. The outer zone comprises about half a radius at each side; the intermediate zone, about one-eighth the radius at each side; and the pseudo-columella, about one-fourth of a diameter. The pseudo-columella appears to be constructed of concentrically arranged vesicles. It is noteworthy that it is divided into two equal parts by a transverse plate which is connected at its ends with two of the septa. There are a few other plates directed radially, but they are not correlated on the opposite sides of the main plate. It would have been most welcome had a longitudinal section been given.

Meek and Worthen's form is under suspicion because it is so much larger than the typical variety. It may belong to *Axophyllum infundibulum* of the same authors so far as the figures show, and it especially resembles the short, partly developed specimen which they include under *A. infundibulum* but which, they suggest, may not be of the same species as the type. The three other citations probably belong together and represent typical *A. rude*, though it must be borne in mind that the three discussions contain very inadequate evidence for reaching a conclusion.

Axophyllum rude seems not to appear among the corals in this collection, but a determination of its characters was a necessary antecedent to the determination of the other related forms.

Axophyllum? sp. A.

This type is represented by a single specimen, a conical, rather rapidly expanding, slightly curved Zaphrentoid coral, 26 mm. in diameter and approximately 40 mm. in length. In transverse section there is seen a small, apparently solid pseudo-columella, slightly elongated and connected at one end with one of the septa. The other septa extend almost to the pseudo-columella but do not connect with it. That structure, though solid, shows radial lines but not concentric ones. One main axis divides it longitudinally and is continuous with the connecting septum. Other plates radiate from the center, three or four on each side, and project as ridges but do not connect with the septa. The septa are 22 in number and can be traced only about half way to the epitheca. They appear to divide so as to inclose elongated cysts and then become lost in the more coarsely cystose structure that forms the peripheral zone. There is another narrow ring of fine cysts adjacent to the epitheca, but these have a concentric instead of a radial arrangement. In transverse section, then, the structures shown are first, fine cysts, then coarse cysts, then fine cysts of which those made by the division of the septa are radially elongated, then a clear zone traversed only by the septa, and lastly, the central pseudo-columella. In longitudinal section only three zones can be recognized; the pseudo-columella which appears like a central rod or pillar, a clear zone not crossed by tabulae or dissepimental tissue, and a very broad cystose peripheral zone made up of small oblique, convex plates piled one above the other. Though these overlap without any regularity they make sigmoidal lines from the epitheca obliquely downward toward the axis, the lines being concave and strongly oblique near the epitheca, about horizontal midway, and convex and more oblique near the pseudo-columella. The edges of the cysts make a sharply defined and continuous inner wall, marking off the peripheral zone from the intermediate one.

Unless this be an abnormal specimen of some of the other types I am at a loss as to the generic relations of this coral, but having only one specimen I hesitate to introduce a new name for what appears to be a novel generic type. It is referred to Axophyllum only as an expedient. In point of the solid axis it agrees more nearly with Lophophyllum though differing in other respects more than it differs from Axophyllum.

Horizon and locality: Kansas City formation—Hertha limestone member, station 423.

Axophyllum? sp. B.

This type can be most briefly described by comparing it with species A which it closely resembles in many ways. It is a nearly straight, rapidly expanding Zaphrentoid coral, having a length of 28 millimeters and a diameter of 20 millimeters. The columella is thin and knife-like and apparently not connected with any of the septa. Both of these peculiarities, in which it differs from species A, may result from the section being in this case located closer to the calice. The septa are solid for only a short distance and then appear, even more conspicuously than in species A., to break up into elongated cysts and they soon lose all identity in the coarsely cystose dissepimental tissue that fills in the peripheral portion. The septa number 22.

The structure as seen in longitudinal section much resembles that of species A save that the intermediate zone which in species A is traversed only by septa is here divided by scattered plates, some nearly flat and horizontal, others curved and oblique.

This is probably generically and specifically the same as species A, but if the differences noted prove to be constant they will constitute a specific difference at least.

Horizon and locality: Kansas City formation—Hertha limestone member, station 423.

Axophyllum? sp. C.

This type also is represented by a single specimen. The shape is more or less cylindrical with a diameter of 15 mm. and a length, in fragmentary condition, of about 25 millimeters. Here again the structure is a variant of that found in species A. The pseudo-columella is small and solid and it is connected with one of the septa, but its radial structure is less distinct and does not result in the formation of projecting angles in the outline. The septa number about 25 and many of the interseptal loculi have secondary septa. The septa divide toward the exterior so as to include a few small cysts, but most of them can be traced nearly or quite to the epitheca. The dissepimental tissue is fine and irregular.

In longitudinal section the outer zone consists of numerous oblique cysts and has a sharply defined inner boundary. The intermediate zone is occupied by much scantier tabulae which are straight or curved, transverse or oblique.

In shape the specimen is like *Axophyllum cylindricum*, but it has a solid pseudo-columella. In having the intermediate zone crossed by tabulae it is like *Axophyllum? sp. B.* In having the septa persistent to, or almost to, the epitheca it differs from *Axophyllum? sp. A*, and *Axophyllum? sp. B.*

Horizon and locality: Kansas City formation—Hertha limestone member, station 423.

Axophyllum? sp. D.

The few specimens included here bear much the relationship to *A. cylindricum* that the form referred to *A. infundibulum* bears to *A. rude*, that is they differ in the imperfect development of the pseudo-columella. They have a cylindrical, more or less contorted shape with a diameter of 10 millimeters and an undetermined length of not less than 35 millimeters. In transverse section three zones are seen. The outer zone is marked by dissepimental tissue; the intermediate zone is fairly clear of such structures; while the pseudo-columella shows the cut edges of closely arranged tabulae intersected by the contorted and confluent ends of many of the septa which reach nearly to the center. The septa number 21 and are all primary septa. But few of them can be traced to the epitheca, being interrupted by some of the cystose dissepimental plates. In longitudinal section the three zones are well differentiated. The peripheral zone is marked by small, thick, oblique cysts, and the central area by thin, shallow and broad, closely-arranged horizontal cysts or tabulae. The intermediate zone has the tabulae much more remote than the central area and more or less complete.

The generic position of this form is much in doubt. It has many points of resemblance to *Axophyllum cylindricum* but can only provisionally be placed in the same genus. The almost complete non-development of the pseudo-columella is one of its most important differences. This is especially shown in the nearly horizontal direction of the tabulae in the axial region, whereas in *A. cylindricum* these plates are arched into a high, acutely angular cone. Nevertheless the central region, even though it could not have projected as a boss, has a differentiated structure similar in many respects to that of the other species.

On the other hand, the structure strikingly resembles that of *Craterophyllum verticillatum.* A conspicuous similarity exists in longitudinal sections between my specimen and Barbour's figure 12 of Plate IV. In his transverse sections less resemblance can be traced as his figures all show a clear central area which the short septa do not penetrate and which exhibits scanty evidence of the tabulae. The greater length of the septa in my specimen would be more of a specific than a generic character and would hardly of itself debar the species from Craterophyllum. It is only as we interpret this and certain other indications as evidence of an aborted pseudo-columella that the species can be placed in the neighborhood of Axophyllum rather than Craterophyllum. That it is a legitimate type of Axophyllum is, however, doubted.

Horizon and locality: Kansas City formation—Hertha limestone member, station 423.

Axophyllum? sp. E.

This group is made principally for three specimens from locality 174 which are known more by their external characters than by their internal. All three show a slightly curved, very rapidly expanding Zaphrentoid coral, the largest specimen being 25 millimeters in diameter and about 25 millimeters long. The calice of this specimen is shallow and an abruptly descending circular depression is formed in the center from which arises a small pseudo-columella marked by longitudinal ridges. The septa number about 56 and are alternating. The calice is campanulate and the septa in it appear as slender ridges on the sides of the central depression and just above, where the calice begins to expand rapidly. At this place the septa die down as ridges and simultaneously narrow grooves are developed in the interseptal loculi and persist to the rim of the calice. Thus all the marginal portion of the calice is nearly smooth, marked only by these narrow radial grooves. The relatively broad, flat spaces between them represent the septa which as ridges appear only well down toward the center. We may look to see this external structure represented internally by a peripheral ring of vesicular tissue not penetrated by the septa.

A section across this coral rather far below the calice, 6 or 7 millimeters from the point of origin, shows a somewhat large, apparently solid pseudo-columella having an elongated shape and connected by one end with one of the septa. Surrounding the pseudo-columella is a clear zone showing the edges of a few tabulae obliquely cut and then comes the wide peripheral zone abundantly supplied with dissepimental plates. The septa number about 21 and there are secondary septa between. They are confined to the peripheral zone, none of them crossing the intermediate zone (save that which connects the pseudo-columella) nor, on the other hand, do they reach to the epitheca, being intercepted by a ring of cystose plates.

The second specimen essentially resembles the first but the expansion is abrupt from a stem-like lower portion. The calice is very broad and shallow as a result of this configuration and it shows several renewals of growth one within the other.

The third specimen is smaller, about 13 millimeters in diameter and 11 millimeters in height. The calice is rather shallow and is crossed by about 58 thin septal plates more or less distinctly alternating. This specimen is of course included with the others only on the supposition that it represents the immature stage, or the central portion, of such a larger form as that first described, and that it would later have developed the flaring outer parts that lack septal ridges but are marked by interseptal grooves, though not having them now.

This form, if all three specimens are conspecific, may well belong with *Axophyllum? sp. A*, although a definite conclusion can not be reached, since the one form is distinguished chiefly on external peculiarities, the internal characters being imperfectly known, while the other form is distinguished chiefly on internal peculiarities, the external characters being imperfectly known.

Horizon and locality: Kansas City formation—Chanute shale member, station 174.

Axophyllum? sp. F.

This form is typified in the collection by a single specimen distinguished by its rapid expansion and by the inverted shape of the calice, of which the rim is much lower than the center. This feature in its present degree may be due to weathering but I do not doubt that the original shape was in the main as it is now. The height is 23 millimeters, of which the height to the rim of the calice is about 18 millimeters. The maximum diameter, for the specimen is not circular, is 33 millimeters. The upper surface of this coral is irregular and the structures unsymmetrical, but in a broad way the upper part of the inverted calice is truncated for a diameter of about 12 millimeters and forms a shallow cup from whose edges the surface descends slightly to the center which is occupied by a large and apparently solid pseudo-columella. The pseudo-columella is oval and has a long diameter of 5 millimeters. It is now more or less worn, and may have projected considerably more than at present. From this central elevation the surface descends to the rim of the epitheca on all sides and it is in different places steep or gradual, and concave, convex, sigmoidal or straight. The septa are thin and numerous. Thirty-four reach to the center and there are an equal number of secondary septa, almost as long. One of the primary septa appears to connect with the pseudo-columella and all the others reach almost to it, but appear to be distinct from it. A rather narrow zone characterized by a scanty development of dissepimental tissue surrounds the pseudo-columella and this is succeeded by a broad, peripheral zone in which interseptal structures abound. In their at present weathered condition these structures have a singular appearance as if the septa were secondary to and produced by the interseptal plates. In other words, except near the center each septum appears to be formed on either side of a thin median line by the infolded and mutually continuous edges of innumerable overlapping interseptal plates. Thus formed, the septa can be traced quite to the epitheca but I would not be surprised, if the structures were presented in their original instead of a worn and abraded condition, to find that the appearance was like that described in *Axophyllum? sp. E.*

In the configuration of the calice this form resembles the one identified as *Lophophyllum alleni* but the size, the shape, and other characters are so different that I would not hesitate to name this as an undescribed species if I were more certain to what extent its present characters are due to wear and to a possible abnormal condition.

Horizon and locality: Kansas City formation—Chanute shale member, station 429a. Shawnee formation—Deer Creek limestone member, stations 165, 191.

Genus Lophophyllum Milne-Edwards and Haime.

Lophophyllum alleni Rowley.

1901. *Axophyllum? alleni.* Rowley, Am. Geol., vol., 27, p. 349, pl. 28, figs. 32-35 Upper Coal Measures: Northwestern Missouri.

This identification has been given to only a few specimens, one or two from each of four localities. They are characterized by their small size, rapid irregular expansion, low altitude, and shallow calice in which the septa round upward so that they project above the rim of the epitheca. The septa are long, reaching nearly to the center, but they die down abruptly and simultaneously, and from the little circular pit thus formed arises the pseudo-columella which is elongated and sharp at both ends and crested along the top. The septa are of two orders but the secondary septa are nearly as long as the primary.

These specimens strikingly resemble Rowley's figures of *Axophyllum? alleni* and agree in most respects with his description. The only notable difference is that he states the number of septa to be about 60 while the septa in many specimens are less than 50. He describes the columella as formed of the upturned inner edges of the lamellae or septa. I scarcely know how to understand this expression which, if taken literally, one might say, is fairly impossible. The most plausible interpretation would be not that the septa make up the columella but that they are continued as ridges up onto it, but even this is not true of my specimens. The pseudo-columella is elongated it is true, but is not, in the calice, connected with any of the septa though, as will immediately be described, it is connected with one of them in the lower part of the corallum.

Rowley was in doubt about the generic position of his coral and apparently had not ascertained some of the diagnostic generic characters. That my specimens appear to belong to a different genus from that to which he referred his species need not be held as evidence against the present identification. My material is too limited to permit an extensive study of structural characters but apparently they indicate a position with Lophopyllum and not with Axophyllum. Two specimens have been ground down so as to show their internal structure and in both of them the pseudo-columella is solid and attached to one of the septa, of which it appears to be an enlargement, but it is free from all the other septa. Furthermore, in one of the specimens especially, the section is sufficiently near to the calice to make it unlikely that the structure observed is that of an immature stage.

If, as seems likely, this form belongs to the genus Lopholyllum, it is readily distinguished from the common species, *L. profundum*, both by its size, its shallow calice and projecting septa, and by the much greater abundance of dissepimental tissue.

Horizon and locality: Douglas formation—Weston shale member, station 301; Iatan limestone member, station 281; Lawrence shale member, station 213. Shawnee formation—Deer Creek limestone member, station 191.

Lophophyllum distortum Worthen.

1875. *Cyathaxonia distorta.* Worthen, Geol. Survey Illinois, Rept., vol. 6, p. 526, pl. 32, fig. 4.
Coal Measures: Cumberland County, Ill.

1898. *Amplexus westii.* Beede, Kansas Univ. Quart., vol. 7, No. 1, Ser. A., p. 17.
Upper Coal Measures: Kansas City, Mo.

1900. *Lophophyllum westi.* Beede, Univ. Geol. Survey Kansas, Rept., vol. 6, p. 18, pl. 2, figs. 8, 8b; pl. 3, fig. 12; pl. 5, fig. 7.
Upper Coal Measures: Kansas City, Lecompton, Neosho County, Kans.

1910. *Cyathaxonia distorta.* Raymond, Carnegie Mus., Annals, vol. 7, No. 1, p. 156, pl. 24, figs. 8, 9.
Vanport limestone: New Castle, Pa.

1911. *Cyathaxonia distorta.* Raymond, Pennsylvania Top. & Geol. Survey, Rept. for 1908-1910, p. 97, pl. 3, fig. 8.
Vanport limestone: New Castle, Pa.

Two species of Lophophyllum are known from the Pennsylvanian of the east—*Lophophyllum profundum* and *Lophophyllum distortum*. *Lophophyllum distortum* was originally described as a Cyathaxonia and stands under that genus at the time of writing. This circumstance does not materially affect the statement just made, because *Lophophyllum profundum* itself was for many years registered as a Cyathaxonia, because Worthen's description, from what it fails to contain, indicates that the internal characters of the species were imperfectly known to him, because from our knowledge of the range of those genera in North America, incomplete as that knowledge is, Lophophyllum rather than Cyathaxonia is to be expected at Pennsylvanian horizons, and because the species is probably identical with another form which if not a Lophophyllum is more closely related to that genus than it is to Cyathaxonia.

Lophophyllum Westi was described by Beede as an Amplexus. He subsequently changed the generic designation to Lophophyllum, at the same time noting that his species might be identical with *Cyathaxonia distorta* Worthen, a relationship which did not suggest itself when *Lophophyllum Westi* was included in a genus that lacks a pseudo-columella. This suggestion seems so probable to me that I am employing Worthen's name for what is undoubtedly the species described by Beede as *Lophophyllum Westi.*

That Beede referred his coral to two genera as widely different as Lophophyllum and Amplexus is not extraordinary when the anomalous structure of *Lophophyllum Westi* is well understood. To omit reference to other characters of less eminent importance, *Lophophyllum Westi* sometimes appears to have the characteristic structure of Lophophyllum and sometimes appears to lack the distinctive pseudo-columella of Lophophyllum and to have essentially the structure of Amplexus. Furthermore these two types of structure in some instances occur in the same coral at different stages of growth. When the Lophophyllum structure is shown, one of the septa is distinguished from the others by reaching to the center or beyond and by having the terminal portion thickened into a slender pseudo-columella. The other septa do not reach the center which is vacant save for this pseudo-columella and for rather abundant irregular tabulae. Neither structure is quite typical for the genus which it seems to resemble, the septa being rather long and the tabulae rather infrequent and irregular for typical Amplexus and the tabulae rather too abundant for typical Lophophyllum. A few longitudinal sections seem to show how these changes from one structure to another take place. Namely, the long pseudo-columellar septum is shortened to the length of its fellows so that the tabulae pass uninterruptedly over the median portion.

The characters possessed by *Lophophyllum profundum* and by *Lophophyllum distortum* are in many respects so widely different as to suggest that both species can not belong to the same genus, and it will be worth while briefly to consider these differences and also to consider which type of structure is most like typical Lophophyllum.

The growth of *Lophophyllum profundum* is short, conical, and curved, the direction of curvature being rather closely oriented with regard to the position of the fossula. The growth of *Lophophyllum Westi* is elongated, cylindrical, and straight. At least if not straight, it is irregularly contorted. It is true on the other hand that the early stages are conical and curved, though it is not known whether the curvature bears any constant relation to the internal structure. The epitheca of *Lophophyllum profundum* is thick; that of *Lophophyllum distortum* is thin. Interseptal tissue is scanty in *Lophophyllum profundum;* it is much more abundant in *Lophophyllum distortum* in which, as seen in cross sections, it usually makes one or two or three concentric rings complete or incomplete as it chances, according as the tabulae are irregular or regular. Schematically the tabulae are large transverse plates flattened over the median portion and curved downward for a greater or less distance about the edges. Accordingly as the tabulae stand at greater or smaller intervals, are straight or oblique and confluent with others differently directed, there would be one or several rings shown in cross section and the rings would be complete or incomplete. In some sections one of these rings connects the inner ends of the septa, having the appearance of an inner wall.

It is in the pseudo-columella that the most important differences between the two forms are found. In *Lophophyllum profundum* the pseudo-columella is large and rod-like, and connected by one end with that one of the septa which lies opposite to the fossula. One or more or sometimes all of the other septa also connect with the pseudo-columella, but possibly this is by secondary deposits. Furthermore the pseudo-columella shows indications of a median plate continuous of course with the septum with which the pseudo-columella itself is connected. Other rays are also sometimes indicated.

In *Lophophyllum distortum,* on the other hand, the pseudo-columella is but the end of the specialized septum scarcely enlarged. It is therefore very thin, instead of cylindrical, and essentially structureless. It rarely if ever unites with the other septa. In a few sections such a union is indicated, but the appearance is better explained, I think, by regarding the connective tissue as of tabular nature. I was for some time doubtful whether a fossula existed in this species; where it can be recognized its position is normal, opposite the pseudo-columella.

In so far as I know the facts, *Lophophyllum profundum* is not in essential agreement with the genus Lophophyllum as based on *Lophophyllum Konincki* which Milne-Edwards and Haime named as the genotype. It has opposite the septum the fossula (the counter septum) connected with the pseudo-columella, not the septum in the fossula (the cardinal septum) as in typical Lophophyllum, and the somewhat obscure radiating structure of the pseudo-columella may not be found in *Lophophyllum Konincki*. Furthermore, the fossula is situated on the convex side of the corallum in *L. Konincki* and on the concave side in *L. profundum*.

Lophophyllum distortum is not typical in its cylindrical shape and possibly in other characters, such as the lack of connection between the pseudo-columella and any of the septa save that which it originates. But above all else is it abnormal in the obsolescence of the pseudo-columella. In some other characters it is more nearly in agreement with *Lophophyllum cruca* upon which Nicholson's observations were based, than is *Lophophyllum profundum*—for instance in the abundance of tabulæ. Nicholson also describes and represents the fossular septum as short and not connected with the pseudo-columella, which is at variance with the statements of Milne-Edwards and Haime. This is more distinctly the condition of *Lophophyllum profundum* than of *Lophophyllum distortum*, but Nicholson also states that the genus does not possess distinct secondary septa, a statement which is not true of neither species.

It may prove desirable to place *L. profundum* and *L. distortum* in different genera or subgenera. If so, the generic name will adhere rather to *L. profundum* than to *L. distortum*, but it may be that neither type will rest under Lophophyllum.

Horizon and locality: Kansas City formation—Iola limestone member, station 215. Douglas formation—Iatan limestone member, station 281; Lawrence shale member, station 213; Oread limestone member, station 273.

Genus Campophyllum Edwards and Haime.

Campophyllum torquium Owen.

1852. *Cyathophyllum (vermiculare?)*. Owen, Geol. Surv. Wisconsin, Iowa, and Minnesota, tab. 4, fig. 2.
Carboniferous limestone: Near mouth of Keg Creek.

1852. *Cyathophyllum torquium.* Owen, idem. tab. 4, fig. 2.
Carboniferous limestone: Near mouth of Keg Creek.

1852. *Cyathophyllum flexuosum* (?). Owen, idem, tab. 4, figs. 3a, b.
Carboniferous limestone: Near mouth of Keg Creek.

1872. *Campophyllum torquium.* Meek, U. S. Geol. Survey Nebraska, Final Rept., p. 145, pl. 1, figs. 1a-d.
Upper Coal Measures: Rock Bluff and Cedar Bluff, Nebraska; Iowa.
Coal Measures: Illinois.

1884. *Campophyllum torquium.* White, Dept. Geol. Nat. Hist. Indiana, 13th Ann. Rept., pt. 2, p. 119, pl. 23, figs. 10-13.
Upper Coal Measures: Iowa; Missouri; Nebraska; Illinois; Indiana.

1894. *Campophyllum torquium.* Keyes, Missouri Geol. Survey, Rept., vol. 4, p. 107, pl. 12, figs. 7a-c; pl. 13, fig. 7.
Coal Measures: Kansas City, Mo.

1898. *Campophyllum torquium.* Beede, Kansas Univ. Quart., vol. 7, no. 4, ser. A., p. 187, figs. 1-4, on p. 190.
Lecompton limestone horizon: Jefferson, Douglas, and Chautauqua counties, Kans.; also near Kansas City, Kans.

1900. *Campophyllum torquium.* Beede, Univ. Geol. Survey Kansas, Rept., vol. 6, p. 19, pl. 4, fig. 1; pl. 5, figs. 1-4.
Coal Measures: Kansas City, Jefferson, Douglas, and Chautauqua counties, Kans.

1904. *Camphophyllum torquum.* Reagan, Indiana Acad. Sci., Proc. for 1903, p. 238, Plate figs. 2a-Cc.
Red Wall Group: Fort Apache, White River, Salt River, Carrixo Creek, and Cibicu Creek, Ariz.

Campophyllum torquium is rather scantily represented in the collections but this material supplemented by that from other areas enables me to note a few facts not perhaps heretofore recorded and to lay emphasis on others. Meek has already called attention to the very thin epitheca possessed by this species, which apparently is not formed as in certain other genera by expansion of the two plates composing the septa. This character might be used more than it appears to have been used for generic and family classification. The structures exhibited comprise three fairly distinct zones, a peripheral zone in which are developed septa and fine dissepimental tissue, an intermediate zone, in which are developed septa and coarse interseptal tissue of a different character from the first, and a central area not penetrated by the septa and crossed only by broad, flat, horizontal tabulae. The existence of a distinct intermediate zone has not, I believe, been clearly pointed out, but the peripheral zone and the central tabulate area have been described and illustrated by several authors.

The narrow peripheral zone is the most sharply defined of the three. In transverse section it appears as a narrow band of fine, dissepimental tissue having a fairly distinct boundary on the inner side. In some specimens the dissepimental network is distinctly finer near the epitheca. The true character of the peripheral zone is best shown in longitudinal section where it is seen to consist of rather fine cysts which overlap so that their plates form a nearly even continuous wall, separating this zone from the intermediate zone adjacent. The intermediate zone extends from the peripheral zone to the extremity of the septa. The edges of a few tabulae or cysts are sometimes seen in it in transverse section, and the septa, which as a rule are thinner and more or less irregular within the boundary of the peripheral zone, thicken distinctly and abruptly as they pass into it. In longitudinal section the closely arranged, flat, horizontal tabulae which are a striking feature of these corals in the central area, become more irregular toward the peripheral zone. They bend abruptly downward, and additional plates, curved or flat, horizontal or oblique, are introduced in greater or less abundance. On comparison with the cross section it appears that the regularly tabulate area seen in the one is co-extensive with the central space left by the inner ends of the septa, seen in the other, while the region of loose irregular dissepimental tissue, of which a part appears to be a continuation, though with changed direction, of the tabulae corresponds with the zone included between the peripheral zone and the inner ends of the septa.

The only really sharp boundary in these structures is the wall, marking the inner limit of the peripheral zone. The cysts of the peripheral zone are small and almost vertical in direction and against the wall formed by the innermost of them the thinner plates of the intermediate zone abut at different angles. The inner boundary of the intermediate zone is of course less sharp but it is fairly distinct as are its structures distinct from those of the axial region.

It is not entirely certain that *Campophyllum torquium* is a true representative of Campophyllum. Milne-Edwards and Haime described Campophyllum as having the interseptal loculi filled with small vesicles and they give a figure of *C. flexuosum*, the type of the genus, in which the vesicles apparently extend to the inner extremity of the septa. As we have already seen the peripheral zone in *C. torquium* is narrow, the septa projecting beyond it for more than half their length. Consequently there are in the American species three distinct zones having different structures, while typical Campophyllum apparently has only two such zones. This difference, even if it is constant, may not be considered as of generic importance.

The specimens from Missouri referred to this species are few in number and mostly of small size. Superficially they suggest *Craterophyllum verticillatum* more than the large cylindrical corals familiar under the name *Campophyllum torquium.* They not only do not show the characteristic gemmation of *C. verticillatum* but the internal structure also is different. At one time Professor Barbour kindly sent me some sketches of *C. verticillatum* for examination and he correctly states my opinion expressed at that time that the form which they represented would better be regarded as a species of Campophyllum than as a new genus. My position was that the structure was essentially similar to that of *C. torquium* and that the budding was not a very practical character for generic use. If the non-verticillate corals associated with *C. verticillatum*, which Professor Barbour says are nearly identical and considerably more numerous, prove to belong to the same species as the other, the character in question would lose greatly in force in validating Craterophyllum as a distinct genus. The internal structure, as Professor Barbour recognizes, is very similar in *Craterophyllum verticillatum* and *Campophyllum torquium*. Both corals show three distinct zones, each zone distinguished by a certain arrangement of the structural elements. There are only two differences of importance which I am able to point out. I have never seen the line of demarcation between the central tabulate area and the intermediate zone as sharply defined in *C. torquium* as it is in some of Professor Barbour's figures of *C. verticillatum*, but that degree of definition seems rather the exception than the rule in *C. verticillatum*. As a second difference, the large cystose plates that are developed in the intermediate zone of *Craterophyllum verticillatum* are directed downward toward the interior while in *Campophyllum torquium* they are directed downward toward the exterior. In some specimens of both species, however, the plates of this zone are so irregular or so approximately horizontal that there is no striking general obliquity in their direction. These are real differences between the two corals but I wish to emphasize the fact that there are in *C. torquium* three distinct zones of structure and that the structures in each zone are essentially the same as in *Craterophyllum verticillatum*.

Horizon and locality: Cherokee shale—Mulky coal horizon, station 307a (?). Kansas City formation—Chanute shale member, stations 174, 416, 424, 429a (?). Douglas formation—Oread limestone member, station 273 (?).

Genus Fistulipora McCoy.

Fistulipora zonata n. sp.

Plate XXIX, figures 1, 2.

Zoarium laminar to sub-hemispheric, attaining a diameter of about 40 millimeters and having an irregular base covered by an epitheca. At irregular periods two or more unusually flat cysts were simultaneously developed, thus producing zones of close texture, separating usually wider zones of loose texture. These zones, manifested primarily in the cysts, appear to have been connected, though less strongly and sharply, with the development of diaphragms in the zooecia. The periodic structure just described has been observed in several specimens and probably is present in all of them in a greater or less degree. The zooecia have an exceedingly brief prostrate stage and appear to spring almost directly from the epitheca in full size. They occur at more or less regular intervals and distinct maculae appear to be absent. Certainly well-defined areas without zooecia are not present. Four zooecia and three interspaces (varying to 3 zooecia and 3 interspaces) occur in 2 millimeters. The interspaces range in size from rather less to rather more than the diameter of the zooecia. The latter vary in absolute measurement from .31 to .36 millimeter in diameter including the walls which have a thickness of about .028 millimeter. The walls of the zooecia have essentially the same thickness as those of the cyst; both are stout. Most of the zooecia are nearly circular in section though nearly always with a slightly petaloid shape. Only here and there is a distinct lunarium seen. Diaphragms cross the zooecial tubes at frequent but irregular intervals which range from less than to more than twice a tube diameter. The cysts are distinctly smaller than the zooecia and occur in one or two rows between them.

It has been customary to refer our Pennsylvanian Fistuliporas to one of the two species, *F. nodulifera* and *F. carbonaria*, though recently Condra has proposed a variety of the latter, *F. carbonaria* var. *nebraskensis*. The present form can scarcely be placed under either species though it is nearer to *F. carbonaria*. It differs, however, in a number of points. *F. carbonaria* is described as having the zooecia about 1-50 inch (or .5 millimeter) in diameter. In *F. zonata* they are much smaller (.36 mm. or less). In *F. carbonaria* they are represented as closely arranged and are never separated by more than one row of cysts. In this form they stand at about their own diameter apart and are separated by one, two, or even three rows of cysts. Possibly my thin sections of *F. zonata* are not oriented so as to show this feature but so far as observed the wall is straight and regular on all sides of the zooecia, quite different from the flexuous or corrugated line of the anterior side in *F. carbonaria*. Finally, *F. carbonaria* has well-marked maculae, a feature of which the present form shows no indication. We have here also the zonate structure of cysts and diaphragms which may not, however, be a specific character.

F. zonata is distinctly more like the variety *nebraskensis* than typical *F. carbonaria* since the variety has smaller zooecia standing at wider intervals than in the principal. The zooecia are in fact even smaller than in *F. zonata* (.28 mm. as against .31 to .36 millimeter). The chief difference would seem to lie in the presence of maculae and monticules in *F. carbonaria* var. *nebraskensis*.

Though apparently distinct from typical *F. carbonaria*, *F. zonata* is perhaps the same form which Condra has identified as that species. His figures and certain parts of his description show differences from typical *F. carbonaria* which are at the same time agreements with *F. zonata*, and it appears not improbable that he may have had not true *F. carbonaria* but the present species. On the other hand his description contains other statements which certainly are at variance with *F. zonata*, such as the citation of maculae and monticules. Some of the verbiage is evidently adopted from the original description of *F. carbonaria*, as the statement that the zooecia are "thin-walled, often contiguous at limited points" a circumstance which suggests that the author combined observations made on specimens actually belonging to *F. zonata* with quotations from the original description of *F. carbonaria* which he supposed to be the same species.

Horizon and locality: Lansing formation—Stanton limestone member, station 690. Douglas formation—Oread limestone member, stations 169, 214, 272, 273, 293. Shawnee formation—Lecompton limestone member, station 288; Deer Creek limestone member, station 165; Calhoun shale member, station 206.

Genus Batostomella Ulrich.

The species here included under the genus Batostomella are not altogether typical and they would, by some writers I suspect, be placed under Rhombopora, at least if certain specimens were withheld from the investigation. I feel fairly confident, however, that these forms are allied to the Batostomellidae and that fact debars serious consideration of the genus Rhombopora, so long as Rhombopora is assigned not only to another family but to another order of Bryozoa. Their relationship to the Batostomellidae is indicated by the presence of maculae (some composed of groups of cells larger than common, others composed of groups of cells having thicker walls than common), by the presence of monticules, by the fact that the walls, though mostly thickened, are over some areas thin as a very knife-edge and that such areas usually abound in young cells (mesopores?) and have the zooecia strongly indented by the large acanthopores. All these characters may not be found in every one of the species here considered but the species are so related that they must, I think, be placed in the same genus. On the other hand, a vestibulum seems to be developed here and there in some specimens, though certainly not now present over most of the surface, while parts of some specimens and especially of slender and apparently immature stems have the regular arrangement and rhombic apertures formed by obliquely intersecting ridges and descending into elliptical tubes, which we are accustomed to consider as characterising the genus Rhombopora.

It seems strange that in practice difficulty should be experienced in distinguishing between genera which are not even assigned to the same order, but the difficulty is not now experienced for the first time and its existence leads me to doubt whether after all Rhombopora really belongs with the other species with which it has been associated and should not more properly find place near, if not in, the Batostomellidae. I shall not try to decide the question, but merely present a few considerations bearing upon it and upon the classification of the Missouri forms.

The structure known as the vestibulum, which is shown in the most typical specimens of Rhombopora, is regarded as one of the characteristics of the genus by which it is distinguished from Batostomella or such genera. Theoretically, perhaps, the importance attached to the structure is not over-estimated. The crucial point is whether a similar appearance is not at times assumed by other types, the structure then being not a true vestibulum, though resembling it. Such a suggestion is demanded by the sporadic occurrence among my speciments of a structure resembling a vestibulum, though my specimens can hardly be placed in Rhombopora without radically modifying the definition of the genus, and I believe changing its taxonomic position.

Another characteristic structure of Rhombopora is its hemisepta. These are not to be observed in all thin sections and certainly not in any of the thin sections of the Missouri specimens. To find this structure is, in my experience, the exception, and here again it may be asked whether hemisepta, or at least structures that may be and have been mistaken for hemisepta do not occur in the Batostomellidae. It is possible that the central perforated diaphragms typical of "Stenopora" (now Tabulipora) might in rare instances have such a misleading appearance. Lee has found moreover that the perforation in an entire group of English species of Tabulipora is not central but marginal and diaphragms constructed in this way are hardly distinguishable from hemisepta. This fact might have an important bearing on the generic assignment of certain species and also on the determination of the relationship of the genus Rhombopora itself.

Rhombopora is also characterized by the absence of mesopores, a character that may be connected with its regular growth. The Missouri species all possess "mesopores" in some degree and in some of them the "mesopores," are very abundant over certain areas, thin walls, abundance of "mesopores," and irregularity of arrangement being in the main correlated characters.

It seems to me a very important matter to distinguish between mesopores and young cells and as a rule this distinction should not be difficult. Scattered apertures of subnormal size would probably best be regarded as merely small or immature zooecia unless their nature as mesopores was fairly well demonstrated by differences such as being subangular while the zooecia are rounded; as being not only uniformly smaller than the zooecia, but not increasing in size; as originating in the cortical zone; possibly as being extremely abundant, and regularly distributed, or as less abundant and arranged in definite groups; or as being tabulate where the zooecia are nontabulate, or vice versa. Employing such criteria in the species from Missouri I would conclude that the small cells were young zooecia and not mesopores. They occur very sporadically and irregularly; they seem not to be distinguished from the zooecia in any way except by size, and the size of the zooecia is so variable that one would be at a loss to say whether certain cells were small zooecia or large "mesopores." In one critical character their nature is doubtful. They appear to be a development of the cortical zone, and if they are so, their nature as mesopores would be pretty well established. The determination of this point, however, is attended with difficulties, and all the deceptive appearances would favor the conclusion that these cells did not extend back into the axial region.

It is obvious that from a merely geometrical standpoint the introduction of new cells through the body of the zoarium is in a measure essential in colonies that have the cylindrical mode of growth. In an explanate growth it would be possible for the zooecia to be parallel and for new ones to be introduced only around the margins of the zoarium, so that increasing height would not bring with it any necessity for filling-in structures. In point of fact many explanate colonies of "Stenopora" (which we must now call Tabulipora) exemplify this plan and show in fact very few small cells. In dome-shaped or hemispherical colonies where the zooecia have more or less of a radial direction some interstitial structures are necessary, but it may be questioned whether the hemispherical shape is due to the introduction of new zooecia, or the introduction of new zooecia is required by the hemispherical shape.

In ramose forms, on the other hand, the zooecia have to meet an entirely new set of geometric conditions which are dual in nature. The stems of course increase in length by the prolongation of cells that are initiated in the axial portion, but bend more or less abruptly outward in the peripheral portion. There they have a radial direction, and it is evident that as they increase in length and as the branch increases in diameter, their apertures become farther and farther apart. There are three ways in which this divergence could be taken care of; by a corresponding increase in the size of the zooecia, which practically never happens, by a corresponding increase in the thickness of the walls, which happens in a minor degree; and by the introduction of new structures such as mesopores and young cells. It appears to be generally true among the "Stenoporas" (Tabuliporas) that the cylindrical and ramose forms have small cells in far greater number than the explanate forms. I think that here the small cells should be regarded as young zooecia and not as mesopores, at least in such types as I have myself seen.

In the cylindrical mode of growth the divergence of the zooecia is greatest in planes perpendicular to the axis of the branch, and is reduced to zero in planes passing through the axis, in which they are parallel to one another. Some types adjust themselves to these diverse conditions by an irregular arrangement accompanied by the introduction of young cells wherever space allows. Thus act many, perhaps all, of the Tabuliporas, so that the ramose forms show the same promiscuous arrangement as the explanate forms. In other types, among them some of the species that I have here, the arrangement is more regular, and it is perhaps a constant feature of such forms that the zooecia are elongated and, *mirabile dictu*, not elongated in a direction transverse to the branch, so as to neutralize their divergence but invariably in a longitudinal direction. It usually happens too that the distance between any two zooecia longitudinally is greater than the distance laterally. I have no explanation to offer for what is undoubtedly a fact and a fact that is apparently a paradox.

It may be that this longitudinally elongated shape of the zooecia marks an immature stage of the zoarium, in which the zooecia, blindly prescient that further enlargement in a longitudinal direction would be impossible, prepare, when the zoarium is forming, for growth in only one direction by assuming full development in the closed direction at the start. By such a hypothesis the lateral divergence between zooecia would be taken up by increase in width and in the thickness of the walls so that a stage would be reached in which the zooecia were circular and the walls of uniform thickness all around them. Some facts seem to support such a theory but nothing at all conclusive.

At all events the arrangement of the zooecia into rows, their elongated shape, their differential spacing, and the development, as often happens, of large acanthopores at the ends of the zooecia and of small granular acanthopores through the rest of the wall, constitute a specialized and more highly developed form of zoarium than the other and might be used if combined with other characters for generic characterization.

I have said that it might be of first importance to know whether the small apertures scattered among the full-sized ones are really mesopores or only immature zooecia, for the reason that the mesopores, the normal zooecia, and the acanthopores are supposed to represent specialized and differently functioning zooids, and it would appear that the kind and degree of such specialization might be used rather more, or rather more uniformly than it has been, in the assembling of genera into families and larger groups. For instance, it might be justified to divide into several genera the numerous and varied forms that now are assembled under Lioclema which are characterized by having true mesopores in great abundance, and to place them in a family distinct from Tabulipora

(Stenopora) in which true mesopores, as I would be inclined to interpret them, are absent. On the other hand, for similar reasons Streblotrypa, which has numerous mesopores, or what might be called mesopores, and no acanthopores except very small ones reported in some species, might be separated from Rhombopora, in which acanthopores are numerous and mesopores absent. These two genera were in fact originally placed in different families but have since been united in one.

As I have already stated the forms from Missouri have been referred to Batostomella though not with entire certainty. The claims of Rhombopora have just been considered. It may be that Stenopora s. s. would be a better genus. It should be borne in mind that Lee has recently shown that typical Stenopora has non-perforated diaphragms and he proposes to restrict the generic name to species so constructed and to revive the abandoned term Tabulipora for species that have perforated diaphragms. All our American Stenoporas must by this proposal be referred to Tabulipora and it deserves consideration whether Stenopora in its new sense is not the same as Batostomella.

The British Tabuliporas show a noteworthy difference from those of North America. One entire group of English species is, so far as known, unrepresented here, that with laterally perforated diaphragms. They are unrepresented, that is, unless by certain of our Rhomboporas. This, however, is unlikely, for the species having laterally perforated diaphragms as a rule show either moniliform walls, or an abundance of diaphragms, or both. In the main, however, the British species are characterized by their ramose growth and by the small size of the stems. Hemispherical and explanate, generally thin-walled species such as are so common in this country, are almost entirely absent in the English fauna whose delicate branched forms are superficially suggestive of our Batostomellas though they have annular walls and perforated diaphragms.

Still more like our Batostomellas, however, are the British Stenoporas, for they not only have the slender ramose shape but also the non-perforated diaphragms of Batostomella. The British Stenoporas, however, have either annular walls or numerous diaphragms, or both, and in these respects differ from Batostomella. Lee recognizes one species of the latter genus in the British fauna, but *B. bundorensis* has rather numerous diaphragms, a considerable proportion of which are centrally perforated, and altogether the reference to Batostomella appears rather doubtful. Although in tangential section the Missouri forms are very like some of the British Stenoporas in having thick walls, rounded zooecia, more or less numerous young cells, and numerous acanthopores of two orders, as is shown in transverse or longitudinal sections, the British forms for the most part have annular walls and numerous diaphragms. Still, the difference of most importance as a generic character, the structure of the walls, varies so much in the British forms that some of them do not differ materially from the species found in Missouri.

Batostomella greeniana n. sp.

Plate XXVII, figures 1-1c.

Zoarium in the form of slender cylindrical stems which branch very irregularly, sometimes at long intervals, sometimes at short intervals, sometimes by bifurcation, sometimes by lateral offshoots. Diameter about 3 millimeters, of which the axial portion comprises $\frac{1}{3}$ more or less and the cortical zone about $\frac{1}{3}$ on each side.

Viewed in the large, these stems show much variation. Some seem to have small circular apertures and thick walls, while others seem to have thinner walls and rather larger and more angular apertures. Provisionally I am regarding the one type as representing the older, the other type as representing the younger condition of the branches. It happens that in the two specimens which most conspicuously show the large-celled, thin-walled condition, large acanthopores are especially numerous. Another explanation of these differences is that the one form represents a worn and the other an unworn condition of the stems. However that may be, I am provisionally including all in the same species.

Without being conspicuously disordered the cells are not arranged according to any fixed plan, and without being conspicuously varied in size small apertures, whether mesopores or young cells, are scattered here and there amongst the mature ones, sometimes almost absent, sometimes much more numerous, but never abundant. In some parts, the zooecia appear to have more or less of a longitudinal arrangement, in some parts an oblique arrangement is conspicuous, but quite as often no arrangement appears. The walls between the zooecia if not worn smooth are covered with fine granules, among which are a few of larger size and much greater projection. There are certain areas where the walls are much thicker than elsewhere. I am doubtful as to the presence of areas distinguished by cells larger than common. Well-marked monticules are certainly not present though the surface of the stems is more or less undulating so that monticular prominences are suggested.

The two young (?) branches selected for sectioning are distinguished as already mentioned by having thinner walls, larger and more angular zooecia and more numerous acanthopores which project far beyond the granules amongst which they occur. One of these specimens also has distinctly more numerous small cells than the other or than the thick-walled specimens. It is not always possible to distinguish small cells from other structures. Weathering may produce a similar appearance possibly at points where large acanthopores have been. Also where the walls are thick and granules occur on them, a pitted appearance is sometimes observed which suggests the presence of mesopores or young cells, but which may be due to open spaces left among the granules.

In tangential sections the zooecia appear as perfectly rounded, nearly circular or distinctly elliptical openings of which about 4 or 5 occur in 2 millimeters. They are regularly arranged, or irregularly, as happens. Small cells or "mesopores" occur here and there but are nowhere abundant. The zooecia have a diameter of .14 to .155 millimeter. In one section in which the zooecia are conspicuously elongated they have the width given above and a length of .21 to .225 millimeter They stand at about their own diameter apart (.14 millimeter) but the distance may be somewhat less, or, on the other hand, vastly more, as much as .35 millimeter. The zooecia are surrounded by a peristomous ring which is not encroached on by the acanthopores and is rather denser (darker) than the rest of the wall. This ring is about .04 millimeter thick. The intermediate portion of the wall, on the average rather less than half the entire thickness, is filled in with large granules or acanthopores arranged in single rows but increasing to three or more where the width of the wall renders it possible. They vary greatly in size, some very small ones being introduced to fill the angles where several of the zooecia come together. These acanthopores are large and closely arranged, always less than their own diameter apart, and often so crowded as to be flattened and polygonal. Among the smaller ones are scattered rather sparingly others of larger size, .085 millimeter in diameter, which are probably normal acanthopores, while the others are granules. The distinction is not, however, well marked as the acanthopores are not much larger than many of the granules. The acanthopores appear to be more regularly rounded than the granules (i.e., less subject to distortion by crowding) and to have a larger axis. Most of the granules show a central point or lumen which is usually small and transparent. In the acanthopores the central point is larger and in one slide it appears to be dark or solid. It is doubtful whether in these specimens there is any distinction in structure between the acanthopores and the granules in the one being concentric and the other granular. Many of the zooecia are surrounded by a circle of minute pores or ostia, sometimes by portions of a second row. The pores have this appearance in tangential sections where the cells are cut transversely and they have the same circular shape when the cells are cut longitudinally (as in longitudinal or transverse sections). It is evident from this that they must be merely points, not tubules. In sections tangent to the tubes, these pores are abundantly and rather regularly distributed. On the other hand, some of the tubes that are cut centrally show a line of these pores down each side close to the surface and it is evident that it is only the wall immediately around the zooecial tube that is thus punctate. The reason why so few of the tubes show these structures when the section is axial or transverse, while so many show them in such abundance when the section is tangent, is difficult to determine. Were the punctae less numerous or more regularly arranged a plausible explanation of their apparent absence in so many of the tubes would be that the sections pass between the rows. From their abundance in sections tangent to the tubes, however, I should certainly expect them to be more numerous in the other sections.

Not much additional is shown in transverse and longitudinal sections, at least that requires comment. There is the usual thin-walled central portion and the thick-walled cortical portion which in this species is relatively thick, apparently $\frac{1}{3}$ of the entire diameter on each side. The zooecia appear to be open throughout, no unquestionable occurrence of diaphragms having been found. The walls make masses of various widths between the zooecia, and are traversed longitudinally by one or more dark bands corresponding to the spines or acanthopores. There are conspicuous structure lines which lead up to them, especially in the peristomous portion of the walls where the fibers are directed obliquely away from the tubes outward toward the surface of the branch. The corresponding descending fibers are less conspicuous on the other side of the spine, but they can usually be seen. Now this is the structure of the normal acanthopore. The large spines supposed from their appearance in tangential section to be normal acanthopores are far less numerous than are these structures as seen in transverse and longitudinal sections, a fact which somewhat suggests that all the spines in this form are normal acanthopores.

Another specimen (no. 130), which is included here but may belong in the variety *regularis*, has a diameter of 3 mm., of which the axial portion constitutes one-third. Superficially the zooecia are elliptical, rather regularly arranged, and separated by walls as thick as the zooecia are wide. I have three tangential sections of this specimen. One has the zooecia somewhat more than 0.14 mm. in width; one somewhat less than 0.14; and the other partly more and partly less. In the first the length of the zooecia is from 0.21 mm. to 0.28 mm.; in the second it is 0.21 mm. or less; and in the third it is about the same as in the second. In this section especially some of the zooecia are nearly circular, while in the first they are conspicuously elongate. The interspaces do not differ materially in the different sections; most of them are from 0.21 mm. to 0.28 mm. in width, but some are 0.14 mm. On the whole more wide interspaces are found between the cells longitudinally than laterally, but this difference is not striking. In a longitudinal direction four zooecia—sometimes four zooecia and one interspace, and in one place perhaps only three zooecia—occur in 2 mm.; in oblique rows five. The acanthopores are much as in the type specimen of the variety *regularis*, except that the large acanthopores are rather smaller and the small ones are rather more numerous. More of the walls have two rows instead of only one (the walls themselves being rather thicker) and more additional acanthopores are introduced where the walls broaden at the junction of several cells. The remaining structures call for little comment. A ring of denser material surrounds the zooecia and the walls adjacent to them possess a punctate structure. Diaphragms appear to be almost absent.

A few specimens included here are very slender but at the same time very irregular in the arrangement of the zooecia. The one character makes their reference to *Rhombopora lepidodendroides*, which they otherwise much resemble, a matter of doubt, and the other makes doubtful their inclusion in the present species, for they are much smaller than normal specimens. Examples of this type were found at station 250 and at station 166.

With some slender stems from station 657, apparently belonging to *B. greeniana*, was found a specimen which appears to be a basal expansion of the same species. It has essentially an incrusting growth but numerous slender stems spring up from it. Mesopores are few. There are many maculae having thick walls, but in the intermediate spaces the walls are moderately thin.

Bastostomella greeniana is distinguished by the small size of the branches, the thick cortical zone, the large and crowded acanthopores and by other characters. In most of these characters it differs from *B. leia* especially in the thick walls, the fewness of its large acanthopores, and the fewness of its "mesopores." In much the same way it differs also from *Batostomella polyspinosa*, which has besides, more numerous "mesopores," and much stronger acanthopores of the large size. One specimen referred to *B. greeniana*, however, has more numerous large acanthopores and more numerous "mesopores" than normal and thus approaches nearer to *B. polyspinosa*. Of all these species, the most similar in some respects is *Batostomella* (*Stenopora*) *spinulosa*. The walls of *B. greeniana* are thicker, and the acanthopores more nearly of a size and more crowded. They are rather smaller than the large ones, and much larger than the smaller ones of *spinulosa*.

Horizon and locality: Cherokee shale, stations 260, 263, 266. Henrietta formation—Ft. Scott limestone member, stations 239, 245, 256; Pawnee limestone member, station 1266a 2 (?). Pleasanton formation, stations 231, 236a (?) 647 (?) 672 (?). Kansas City formation—Bethany Falls limestone member, station 250 (?); Chanute shale member, station 166. Lansing formation—Lane shale member, stations 285, 285a, 657; Plattsburg limestone member, station 295 (?); Stanton limestone member, station 290a. Douglas formation—Iatan limestone member, station 289; Lawrence shale member, stations 205, 208, 283; Oread limestone member, stations 170, 225, 303. Shawnee formation—Lecompton limestone member, station 224; Calhoun shale member, station 197; Topeka limestone member, stations 179, 180, 211; Severy shale member, stations 212, 228 (?).

Batostomella greeniana var. regularis n. var.

This variety is rather abundant at station 180 where it is associated with typical *B. greeniana*. It is a slender branching form, ranging in diameter from 1¼ millimeters to almost 3 millimeters. The branching is irregular and commonly by bifurcation (much less often by lateral offshoots); it may also occur at either long or short intervals. The longest unbranched fragment is 14 mm.

Superficially the branches show elliptical apertures rather regularly arranged in quincunx and consequently forming longitudinal and oblique rows. The intervals separating the apertures are rather wide. In certain areas, however, the arrangement is irregular and among the zooecia of normal size are distributed more or less numerous small ones. Furthermore, there are small areas which have walls of more than usual thickness and some of these project as low monticules. There are also much larger areas in which the walls are abnormally thin, and some of these also project as monticules. As a rule, thinness of wall, irregularity of zooecial arrangement, and abundance of small cells go together, and areas possessing such characters occur on stems on which regular arrangement, absence of small cells, and thick walls prevail.

The spaces between the zooecia, that is the tops of the walls, are flat, but they may be very thin and reduced to mere edges. Only rarely, and then only locally, do the apertures appear vestibulate; as a rule the walls at the aperture descend abruptly without inwardly sloping sides. The tops of the walls, when not worn, are covered with granules, among which occur much larger and more projecting spines, located at the angles where three or more cells corner. Often the tops of the walls present the appearance of being pitted instead of granular, and sometimes the pits are so deep that the zooecia appear to be surrounded by numerous mesopores. Probably the other interpretation is preferable, for these pits are after all superficial as compared with the small apertures which have sometime been called mesopores.

One of the specimens sectioned (no. 16) is about 2½ millimeters in diameter, of which the axial portion constitutes rather less than a third. Its length is 18 millimeters and it developed several branches. The surface is exceptionally well preserved. Over part of it the crests of the walls make rather straight oblique lines which are furnished with acanthopores at their intersections, and with granules along the intervening portions. This part may be vestibulated. Over another part the arrangement of the zooecia is irregular, the walls are thicker, their flat tops furnished with acanthopores and several rows of granules. Small cells are relatively numerous. There are several small prominences, some with walls uncommonly thick, and some with walls uncommonly thin. Still a third aspect is presented by part of the surface which shows irregular angular cells interspersed with numerous small cells and separated by thin walls. Acanthopores here are very large.

Tangential sections of this specimen show rather regularly arranged elliptical apertures about 0.14 millimeter in width, some more, some less, and about 0.21 mm. more or less in length. The intervals between them are also about 0.14 millimeter wide but some are much wider, as wide as 0.28 millimeter, or even 0.35 millimeter. The walls are not conspicuously thicker at the ends of the zooecia than at their sides. The acanthopores are very large — some of them as much as 0.11 millimeter in diameter. They alternate with the zooecia in longitudinal rows and some of them flatten the end of the cell above or below, giving it an ovate shape. Much smaller, though still rather large granular acanthopores, make single rows down the intervening wall spaces. About 5 zooecia longitudinally and 6 obliquely occur in 2 millimeters. The zooecia have a denser peristomous ring and some of them show a row of minute foramina surrounding the aperture.

Another specimen (number 122) has a diameter of about 2 mm. and a very thin cortical zone, about .21 mm. thick. The zooecia have a width in cross section of .11 mm., some a little more or a little less, and the length is .17 mm., varying somewhat in different cells. The walls laterally average about .14 mm. but some are as thick as .21 mm., and some as thin as .1 mm. Longitudinally the average is close to .28 mm., but some are .35 mm. and some .21 mm. This does not include instances of irregular arrangement where one zooecium does not follow another in a straight line but stands a little to one side or the other. In that case the distance between them is narrower. Six or seven of the zooecia occur in 2 mm. in oblique rows. In the same distance longitudinally 4 zooecia and 4 interspaces occur, but the zooecia are not so regular that an end to end arrangement can be found for any considerable distance, and if they are a little oblique, the number occurring in 2 mm. is appreciably greater. Almost invariably each zooecium has a large acanthopore at one end, between it and the next zooecium above or below, but the acanthopore is rarely midway in position and may be so close to one of the zooecia as to flatten the end. Moreover, the same arrangement obtains generally, the zooecia regularly having the acanthopores near the distal or the proximal end, whichever it may be. Exceptions occur, as when the acanthopore is almost intermediate or when, rarely 2 acanthopores are developed, one near one zooecium and the other near the other. Secondary acanthopores of various size are present, the largest much smaller than the large acanthopores. They occur in one, two, or three rows, according to the width of the walls, but the narrowest parts of the walls do not have any at all. Diaphragms appear to be absent, but the sections are not favorable for showing their presence. In one place the usual punctate wall structure is shown close to the tube, but no other evidence of this was observed.

This differs from the other specimen described in detail (number 16), which is the type specimen, in several minor particulars, but especially in having a much thinner cortical zone. Lee found that in the English species the thickness of the cortical zone bore a constant ratio to the diameter of the stem. If the same principle were employed in distinguishing species in the material from Missouri these two specimens would certainly represent different species. As such they may come to be regarded, but my observations lead me to doubt the value of this character as applied to American forms.

This variety differs from typical *B. greeniana* in the more regular arrangement of the zooecia, in their more elongated shape, in the fewer and smaller granular acanthopores, and in the relatively larger normal acanthopores.

Among the unusual or abnormal types included under this variety are a few specimens from station 170 which have conspicuous monticules and seem, from a superficial examination, to be without large, spine-like acanthopores. Monticules are a rather rare and minor feature of this type, and the subordination of the large acanthopores is more normal to true *B. greeniana* than to the variety *regularis*.

Horizon and locality: Kansas City formation—Cherryvale shale member, stations 167, 210; Drum limestone member, station 429; Chanute shale member, station 429a (?). Lansing formation—Lane shale member, stations 163, 663. Douglas formation—Oread limestone member, stations 170, 273. Shawnee formation—Topeka limestone member, station 180.

Batostomella (?) polyspinosa Condra.

1902. *Stenopora (?) polyspinosa.* Condra, Am. Geol., vol. 30, p. 341, pl. 20, figs. 6-10.
Coal Measures: South Bend, Nebr.

1903. *Stenopora (?) polyspinosa.* Condra, Nebraska Geol. Survey, Rept., vol. 2, pt. 1, p. 46; pl. 5, figs. 1-5; pl. 6, fig. 1.
Coal Measures: South Bend, La Platte, Bennett, and Tablerock, Nebr.

1906. *Stenopora (?) polyspinosa.* Woodruff, Nebraska Geol. Survey, Rept., vol. 2, pt. 2, pl. 9, fig. 1.
Carboniferous: Cass Co., Nebr.

The specimens chiefly considered here were obtained at Station 180 where they are fairly abundant. They comprise subcylindrical stems, circular to elliptical in section, and mostly from 3 to 5 millimeters in diameter. Some specimens are crushed flat, apparently having become hollowed out and then easily yielding to pressure. The stems are not straight, neither are they strongly bent. Branching appears to have been fairly frequent but irregular. Some specimens 25 or even 35 millimeters long show no indication of branching, while others have branched twice in 25 millimeters; for instance one with the points of branching 10 millimeters and another 15 millimeters apart. The branching may be lateral or bifurcatory and at various angles.

The details of structure vary as widely as the form of the branches. In general the cell walls are rather thick, and furnished with one or two rows of small granules. Where the stems are worn the granules are inconspicuous, at least as projections, though under certain conditions they can still be seen owing to their different density from the rest of the wall. The thickness of the walls varies considerably in different specimens and different parts of the same specimen. Small areas having distinctly thicker walls than the average form obscure maculae which sometimes project as low monticules. A few specimens, as in some from station 208, have very prominent monticules. Here and there groups of unusually large cells appear to form maculae of another sort. In some specimens, for no apparent reason, considerable areas show walls thinner than elsewhere. The zooecia are subcircular, usually more or less elongated, more or less irregular in shape, and of various sizes. They have no regularity of arrangement. Some of the very small openings might be regarded as mesopores though nothing but size distinguishes them from the mature zooecia. These small cells (or mesopores?) are usually sparingly developed. In some areas, however, they are abundant and as numerous as, or even more numerous than, the cells of normal size. The condition of abundant "mesopores" is apt to be correlated with that of thin zooecial walls, and where the walls are thin or the "mesopores" absent, the zooecia are apt to be correspondingly large, as if the number of zooecia normal to a certain area were constant and a thinning of the walls below normal were compensated either by an increase in the size of the zooecia or by the development of an unusual number of "mesopores."

In describing the more minute structure of this form I shall distinguish several different types disclosed by thin sections. It is not thought that these differences characterize whole colonies so that they might perhaps be used for purpose of classification. Instead, they appear to occur on different parts of the same stem. In general it may be said that the cortical or mature and thick-walled region is rather sharply marked off from the thin-walled axial region. In some of the larger specimens which have a diameter of about 6 millimeters, the cortical zone has a thickness of 1½ millimeters or a little more, so that the axial portion comprises about ½ of the whole diameter. A smaller specimen 4 millimeters in diameter has a mature zone somewhat less than 1 millimeter in thickness, so that here also the axial portion makes up about ½ the diameter or a little less.

As seen in tangential section the zooecia are surrounded by a ring of material darker than that which composes the rest of the wall, indicating the presence of a sort of peristome. This structure has no distinct boundary from the rest of the wall and is more noticeable in some sections than in others. Spines of two sorts are present, regular acanthopores showing concentric structure and smaller spines apparently made up of aggregated granules or dots of microscopic size. In species related to this, one of which Ulrich has described as *Rhombopora crassa*, the inner margin of the peristome shows a row of minute foramina suggesting tubules, and these are shown (again as apparently minute orifices or punctae) when the walls are cut parallel to the tubes and tangent to them. I am not sure that I have observed in the present species the phenomenon first described (the ring of foramina surrounding the zooecial tubes) but the second phenomenon is shown many times so that the presence of these structures may be inferred.

Of the several types of structure which I shall describe particularly, one is characterized by having the walls thin and the zooecial tubes large. In this type the zooecia are irregular in size, in shape, and in arrangement; but the shape is always subcircular. It is rare that 7 zooecia occur in 2 millimeters, and the size, though variable and ranging up to .28 millimeter in diameter, is on an average about .25 millimeter in diameter. The interspaces range in thickness from almost linear to almost a cell diameter. The average is ⅓ to ¼ of a cell diameter or about .07 millimeter. Small cells are fairly numerous and there is almost every gradation in size up to the dimension for the mature condition already given. The walls are furnished with a single row of large granules. Where they are very thin the granules are absent. The triangular areas where three cells come together may be occupied by three of the granules, by an acanthopore, or by a young cell. The acanthopores are rather numerous and rather large; 1 to 4 may be found near each zooecium. Some of them indent the cells. This form strikingly resembles *Batostomella polyspinosa* and the identification is offered with confidence.

A type with somewhat thicker walls and smaller cells is also shown by my sections. The zooecia here range in diameter from .18 millimeter to .28 millimeter with an average of about .21 millimeter. The walls vary in thickness from ¼ to 1 cell diameter, with an average of about ⅓ diameter (.07 millimeter). Small cells are rather scarce in one specimen, abundant in another. The granular acanthopores occur in single rows between the zooecia but where the walls are unusually thick they increase to two or three rows. In these sections normal acanthopores appear to be rather less numerous, are, in fact, almost absent over some areas though fairly abundant in others.

In a third type of structure the zooecia are distinctly elliptical in shape and more regular in arrangement, manifesting a marked tendency to form longitudinal and oblique rows. The size here ranges from .18 to .24 millimeter in length with an average of .21, and the average width is .14 millimeter. The interspaces range from about ⅓ to 1½ the width of the tubes, the average being about .113 to .141 millimeter. The intervals laterally seem not to show any regular difference from the intervals longitudinally. Five or six zooecia occur in 2 millimeters longitudinally and 6 or 7 in the same distance transversely. The granular acanthopores occur normally in a single row but as usual, where the walls are especially thick a second or even a third row is found. Furthermore, some of the granular acanthopores are much smaller than others (a phenomenon more conspicuous in this than in the other sections) and these smaller acanthopores make incomplete rows where the interspaces widen at the cell angles. True acanthopores are present but they occur at irregular intervals, close together in one place with almost every cell angle occupied by them, and far apart in another place with three or four cells between. Some of them strongly indent the tubes.

The foregoing description is considerably generalized and it may be of service to describe a few individual specimens of this variable form.

Specimen 12. This specimen is regularly cylindrical, slightly curved, and has a length of 35 mm.; it is without branches. The diameter is 5½ mm., of which the cortical zone comprises about 1¾ mm. on each side, and the axial region about 2 mm. Monticules composed of cells having a larger size and thicker walls than normal are unmistakably present, but they are small and low. Superficially the zooecia are irregularly arranged and subcircular, though varying much in size. Distinctly small cells (mesopores?) are not numerous. The walls also vary considerably, but no areas of extreme thickness have been noted. Longitudinal and transverse sections show little requiring comment. Punctate structure has not been definitely ascertained in the walls surrounding the zooecial tubes in these sections. The presence of diaphragms also is not shown. In tangential sections the cells are rounded or somewhat polygonal. Though the zooecia and the walls especially, vary a great deal, the thickness of the walls appears to be about one-half the diameter of the zooecia. The very largest zooecia are perhaps .28 mm. in diameter, but the average is about .21 mm. Similarly, while the interspaces sometimes are as thick as .28 mm. they are more often as thin as .07 mm. The average is .17 mm., or even less. In these sections large acanthopores are almost wanting, and but few "mesopores" appear. The smaller acanthopores, on the other hand, are numerous. They are closely arranged, mostly in single rows down the median line of the walls. Each has a light-colored center (axial tube) and appears to be made up of granules. Some of these acanthopores indent the cells.

Specimen 13. This specimen is 26 mm. long and has a partially developed lateral branch at the lower end. The diameter is 6 mm., of which the cortical zone occupies nearly 2 mm. at each side. This stem is nearly straight and regularly cylindrical, with scarcely any evidence of monticules. There are, nevertheless, areas characterized by large cells and other areas characterized by thick walls. On the whole, this specimen is much more thin walled than no. 12, many of the walls being almost linear. Great disparity also is manifested in the size and shape of the zooecia and in the thickness of the walls. Small cells are relatively numerous, and large acanthopores if not worn off make spine-like projections from the cell angles. In longitudinal and transverse sections one or rarely two complete diaphragms are shown in some of the tubes, and the coarsely punctate structure of the walls lining them is very conspicuous. Tangential sections exhibit most of the characters observed on the surface:—the thin walls, the circular to more or less polygonal zooecia, the numerous "mesopores," and the abundant large acanthopores. The thickness of the walls in this specimen varies from one-third to one-fourth the diameter of the zooecia. The zooecia themselves average rather larger than those of specimen 12. The largest has a diameter of .35 mm. and the average may be about .23 mm. Seven occur in a linear distance of 2 mm. The walls vary in thickness from .03 mm. to .14 mm. with an average of about .07. Large acanthopores are numerous, yet many cell angles are without them. The small acanthopores are smaller than in specimen 12 or, where the walls are thin, are absent altogether, but they occur in single rows (rarely in double rows) where the walls are thick. Some of the large acanthopores and some of the small ones indent the cells.

Specimen 126. This specimen is a fragment which consists of a stem and its two branches, all three of about the same size. Superficially, it resembles the foregoing specimen (number 13) in its rather thin walls and rather numerous "mesopores," but the walls are not quite so thin and the acanthopores appear to be less numerous. The diameter of the specimen is about 5 mm., of which the cortical zone comprises about 1½ mm. on each side. A longitudinal section demonstrates the presence of diaphragms (rare) and indicates a punctate structure for the lining of the zooecial tubes. My tangential sections show a greater irregularity of arrangement and a greater development of "mesopores" than would appear to characterize the zooarium as a whole. About 6 zooecia occur in a distance of 2 mm., but it is difficult to find 6 or 7 zooecia which form even an approximately straight line. The zooecia vary so much in size that it is hardly practicable to give an average. Many of them measure nearly or quite .28 mm. in diameter, the walls ranging in thickness from .07 mm. to .28 mm., with an average of about .14 mm. In a general survey of a tangential section, it would appear that the walls averaged half, or rather less than half the diameter of the zooecia. Large acanthopores appear to be rather more numerous than in specimen 12, but less numerous than in specimen 13. The small acanthopores are somewhat more numerous than in either, and more of the walls have two rows or parts of two rows. A number of the cells are indented by one kind of acanthopore or the other, but otherwise the cells are nearly circular in section. A peristomous ring is clearly shown.

Specimen 128. Of the superficial character of this specimen, little can be said, as it is in large part covered by a growth of Fistulipora. It shows part of a stem which at the distance of 20 mm. divides into two branches. The walls appear to be rather thick and the zooecia rounded, nearly circular in one part of the zooarium, and elongated or elliptical in another. The diameter of the stem is 6 mm., and the cortical zone slightly less than 2 mm. in thickness. Diaphragms are not shown by my sections, but the walls adjacent to the zooecia are abundantly and coarsely punctate. In both my tangential sections the zooecia, though more or less irregular in arrangement, and though more or less interspersed with small cells, show a distinct tendency to occur in longitudinal rows and to be elongated in the direction of the rows. About 6 zooecia longitudinally and 6 or 7 transversely, occur in 2 mm. The thickness of the walls appears to be about equal to the short diameter of the zooecia, and not much difference is manifested whether the thickness is measured at the ends of the zooecia or at their sides. If anything, the lateral distance between the zooecia (about .18 mm.) is greater than the longitudinal (about .14 mm.). The zooecia range from about .21 mm. to .28 mm. in length, with an average of about .24 mm. Most of them have a width of about .14 mm. Large acanthopores are rather numerous in one section and rather rare in the other, and some of them indent the cells. Rarely do they occur at the ends of the zooecia, the usual position being near the end but off to one side. The small acanthopores are of several sizes, and occur in single or double rows or partial rows, or form small groups where three or four cells come together.

Most of my identifications of this and other species of Batostomella have of course been made without the aid of thin sections. Characteristic specimens of *B. polyspinosa* can readily be distinguished by external characters from characteristic specimens of *B. greeniana*, for they have larger branches, thinner walls, larger zooecia, and more numerous young cells. The larger branches and thinner walls are the most salient differences. On the other hand *B. greeniana* var. *regularis* is still further distinguished by the elongated shape of the zooecia and their regular arrangement. Nevertheless there are specimens which are typical of neither species, and these need further study. These stems agree with *B. greeniana* in being slender, but they agree with *B. polyspinosa* in having the walls thin, the zooecia very irregularly arranged, and the young cells dispersed among them more or less numerous. The opposite condition, agreement with *B. polyspinosa* in the size of the stems and with *B. greeniana* in the thickness of the walls and other characters, occurs rarely if at all. Conspicuous examples of such slender stems having the general structure of *B. polyspinosa* have been found at station 278, station 284, station 200 where the specimens have thin walls, numerous mesopores (?) and very irregularly arranged zooecia, station 168, station 644, station 210, and station 677 where again the arrangement is very irregular, the walls very thin, and the small cells numerous.

Several specimens from which thin sections were made appear to belong to this group. One (no. 131) has the zooecia irregularly arranged, and the walls uniformly and moderately thickened. The diameter of this specimen is 2.5 mm. and the cortical zone is notably thin, being only about 0.25 mm. on each side, while the axial region is 2 mm.

The two tangential sections show elliptical zooecia rather regularly and closely arranged. In one place a number of "mesopores" occur. The width of the zooecia is rather uniformly about 0.14 mm. and the length, though varying considerably, averages

0.21 mm. In one section the interspaces range from 0.07 mm. to 0.14 mm. in width. In the other they are distinctly thinner for though the range is not greatly different, very few are as thick as 0.14 mm. and many are as thin as 0.07 mm., while some are even thinner. However, as this specimen has such a thin cortical zone the section may owe this peculiarity to being cut closer to the axial region. The walls develop granular acanthopores in proportion to their width, the thinnest walls showing them only in the thickest portions. The normal acanthopores are rather small.

Another specimen (no. 18) has a diameter of less than 3 mm. and a thin cortical zone. The zooecia are slightly elongated. The walls are in places linear with large to medium normal acanthopores, but range to moderate thickness (½ the small diameter of the zooecia) with rather numerous granular acanthopores, and medium sized normal acanthopores. These two specimens are from station 180.

Two specimens from station 210 also probably belong in this group. They have a diameter of about 3 mm. The cylindrical branches are irregular, but they are without distinct monticules. The zooecia are irregular in arrangement and more or less circular in section.

The interspaces are in some places unusually thin, in others unusually thick. Large acanthopores are located at all or nearly all of the points where three or more cells come together.

Thin sections have been made from one of the specimens (no. 116), one transverse, one longitudinal, and two tangential. The diameter of the specimen is rather less than 3½ mm., of which the axial portion occupies about 2½ mm., the cortical zone being only .42 mm. or less in thickness. The walls show very unsatisfactory evidence of being punctate at the surface of the zooecial tubes. Diaphragms are scantily developed and occur far down in the zooecia, below the mature zone. The transverse section exhibits the unusual character of acanthopores in the thin-walled axial region well back from the cortical zone.

One of the tangential sections shows nearly circular zooecia separated by walls of about their own diameter which are mounted with numerous large and small acanthopores. Six zooecia, less often five or seven occur in 2 mm. The zooecia have a diameter of .17 mm. Fewer attain this diameter than exceed it. The walls range in thickness from .07 mm. to .28 mm., but most of them have a thickness of about .14 mm. Large acanthopores occur at most of the intersections of the walls; some of them have a diameter of .1 mm. Granular acanthopores of various sizes, but less than half as large as the others, occur mostly in single rows down the central line of the walls. Where the walls are unusually thick, several rows are developed and small ones fill in the unoccupied portions, but always a peristomous ring is left about each zooecium. A few "mesopores" are present.

The second tangential section is slightly oblique as is shown by distortion of the large acanthopores. Owing doubtless to this fact the zooecia here are elliptical instead of circular and the thin-walled condition exhibited by one end of the section is probably best attributed to the same cause (the obliquity of the section carrying it below the thin cortical zone) though it may be normal. In this part of the section the walls are linear and the cells polygonal: small acanthopores are absent and large ones are much reduced in size. They indent the cells at the angles where they occur. Small cells or "mesopores" are present, and they are also scattered among the zooecia in the rest of the section.

The zooecia in this section, as already noted, are elongate but their shape may be due to a slight obliquity of the section. If so, the irregularity is rectified immediately, since the orientation of the thin-walled portion of it appears to be true. Six, rarely seven, occur in 2 mm. Many are as wide as .14 mm., but not a few are less. The average length is rather less than .21 mm., but many are as long as that, and a few are longer. The walls have an average width of about .14 mm. The variation in thickness of the walls is much greater than the variation in diameter of the zooecia. The zooecia increase in size and the walls diminish in thickness as the thin-walled part of the section is approached, where, as indicated by the more symmetrical shape, the orientation of the section is corrected. The remaining characters are as in the other section except that the large acanthopores appear to be rather smaller.

Lastly there must also probably be included here Specimen 127. This is a small fragment, only 10 mm. long and about 4 mm. in diameter. Insofar as its characters are shown, this specimen appears to be without maculae or monticules and to have the walls uniformly rather thick and the zooecia of nearly uniform size, round or elliptical. The cortical zone is unusually thin, rather less than 1 mm., so that the axial portion is rather more than 2 mm. in diameter. Tangential and longitudinal sections show punctate structure in the walls contiguous to the zooecia, but fail to indicate the presence of diaphragms. Both my tangential sections show the zooecia to be elliptical in cross section, but they are irregularly arranged in one section and tend to be arranged in longitudinal rows in the other. Six occur longitudinally in 2 mm. The two sections differ somewhat in the size of the zooecia. In one many of the zooecia have a length of .21 mm., though many are smaller and few larger. In the other section not a few of the zooecia have a length of .28 mm., and in both a few are as small as .14 mm. or even smaller, if certain small apertures are regarded as zooecia instead of "mesopores." The average width of the zooecia can probably be stated as .14 mm. though some are as wide as .21 mm. and others smaller than .14 mm. The walls vary considerably, but appear to average about one-half the diameter of the zooecia. The maximum variation is from .04 to .18 mm., but most of the walls are between .07 mm. and .11 mm. thick. The average is probably about .1 mm. Large acanthopores (in this specimen not very large, few being over .07 mm. in diameter) are fairly numerous and many of them occur close to the ends of the zooecia, which they flatten or indent. Others occur between the zooecia laterally, but as the zooecia are not regularly arranged, those which are at the ends of certain zooecia may be more or less lateral to others.

It will be observed that these specimens have a thick axial portion and a thin cortical zone. I am unable to state that the same relation exists in all the slender stems superficially resembling *B. polyspinosa*, but such is probably the case. Like typical *B. polyspinosa* these specimens have the axial or immature portion approximately 2 mm. in diameter, their smaller total diameter being due to their narrower cortical zone. The axial region in *B. greeniana* on the other hand is only about 1 mm. in diameter, but the cortical zone is developed to an equal thickness all around producing a stem in total thickness about equal to those under consideration.

These slender, thin-walled, thin-cortexed specimens are referred to *B. polyspinosa* on the assumption that they are stems that have not attained their full size and in which further growth would have increased the thickness of the cortical zone, without increasing the thickness of the walls or otherwise greatly modifying the structures of that portion. Now among ramose types of the Batostomellidae the size of the stem is, within certain limits considered a character of specific importance. It also seems to be generally and rightly held, that between a stage which may justly be called immature (the axial, thin walled, or immature region) and certain rare conditions which may justly be called senile, these stems exhibit a mature stage (the cortical or mature zone) in which the structures are essentially constant throughout. In both *B. polyspinosa* and *B. greeniana* the cortical zone is thick, normally about equal to the diameter of the inner axial portion. In both species then, specimens might range in size down to ⅓ the maximum diameter and yet display normal mature characters in every stage. Such characters then, in the case of *B. polyspinosa*, might be expected in stems ranging from 6 mm. to about 2 mm. in diameter.

It has been said that after the mature stage has once been initiated its structural characters remain essentially constant. In one respect a certain amount of change seems almost a geometric necessity. It is obvious that in the ramose mode of growth the zooecial tubes must be parallel lengthwise of the stem, else the stem would come to an end. It must be equally obvious that transversely to the stem the zooecial tubes have a radial direction, and that the thicker grows the cortical zone, the farther are the zooecial tubes apart at the surface. Various ways of taking up this divergence at once suggest themselves, such as an increase in the size of the zooecial tubes, or an increase in the thickness of the walls, or the introduction of new zooecia, or a readjustment of the old zooecia, or in forms possessing mesopores, the introduction of these structures especially at the sides of the zooecia. In point of fact, one could almost say that none of these compensating developments do, and that some of them cannot take place. Increase in the size of the zooecial tubes could only take place in the direction of planes transverse to the axis of the branch. Strange to say, the zooecial apertures are often elongated, but always in a direction longitudinal to the stem, while thin sections show that the zooecial tubes are essentially cylindrical. It may be, however, that the zooecia have an elliptical cross section in the earlier and a circular cross section in the latter portions of the cortical zone, and that the divergence is too slight to be conspicuous in thin sections cut transversely to the branch. Similiarly, a differential thickening of the walls is a common feature of these forms, but the thicker walls regularly occur at the ends of the zooecia, not at their sides, in line with the long axis of the apertures, not with their short axis. Theoretically new zooecia must originate in the axial region and have a long, thin-walled, axial portion. The more or less numerous small cells which occur among those of normal size and which appear to originate in the cortical zone cannot be true zooecia, if they so originate, and they must be regarded as mesopores even though they have no special structures to distinguish them. As for the more typical and obvious sort of mesopores, their distribution tends to be symmetrical wherever any definite arrangement can be detected.

It remains only to discuss a possible readjustment of the zooecia themselves. I know not whether such a process could take place; it could only come about through a settling of the zooids outside of the skeleton already deposited. It at least seems to be true that such a process would result in a distortion of the zooecial tubes such as, I believe, is never observed.

That such stems as we are considering do increase in girth as well as in length is obvious, but the use of size as a specific character implies that in each species there is a certain limit in their enlargement beyond which increase is slow or at which it possibly ceases altogether, so that in each species completely developed branches maintain a reasonable uniformity in size. This also raises the question of a minimum as well as a maximum limit of size, and the other related question whether the structure of the branches is not modified as the size increases from small to large. Barring subsequent changes, it would appear that the minimum size of such stems as these, in which the zooecial tubes change more or less abruptly from a longitudinal direction and a thin-walled condition in the central part of the stem, to a radial direction and a thick-walled condition in the cortical part, was fixed and predetermined by the size of the immature or axial thin-walled portion. The diameter of this axial portion might conceivably vary in different parts of the same stem, but since its diameter depends upon the number and size of the zooecia and upon the length of the immature condition (which partly determines the number of zooecia in the axial region at a given stage) and since these factors are probably essentially constant, we may conclude that such fluctuations are not common and that irregularities in size are due to irregularities in thickness of the mature zone. If I understand him aright, Lee believes that while secretions are being added to the outer side of the thick-walled cortical zone, resorption is taking place on its inner side so that the axial region grows in size as well as the cortical zone, and a constant ratio is maintained between them. This ratio, then, becomes a feature of specific importance and Lee uses it as such in his classification of the British species. The opposite process might also take place, and secondary deposits might be added on the inner side of the cortex thus diminishing, as the other process increased, the size of the thin-walled axial region. Small changes by resorption or accretion might be very difficult to detect especially in types in which the change from the immature to the mature condition was gradual and not accompanied by an abrupt change in the thickness of the wall and especially in the direction of the tube.

I am inclined to doubt the activity of either process to an appreciable degree in the forms which I have myself examined, and in the group of forms which I am considering it appears to me that the diameter of the immature zone after being once established remained essentially constant. I am also inclined to believe that in these forms the axial portion, instead of maintaining a constant ratio to the cortical zone, is itself constant within the limits of a species, and that the ratio is an ever-varying one until the full growth of the stem is attained—that the ratio is constant for all full-grown stems of a species, but not constant for the growth of any single stem.

It is, however, debatable whether the last off-shoots of a large ramose colony, even when fully developed, might not have a smaller total girth and a smaller axial portion than the main trunk and branches. Still, if a stem starts out with a certain number of cells in the axial region, having a certain size, and continued to a certain length before bending outward and assuming mature characters, it seems probable that the same number, and size, and length would be maintained in subsequent branchings, and also that if another colony showed marked differences in those characters, the differences should be considered as specific differences.

The character of the ramification also seems to be considered more or less of a specific character, and perhaps in some types greater regularity is maintained. The forms from Missouri, however, seem to branch at the most irregular intervals, at almost any angle, and by lateral off-shoots or by bifurcation indiscriminately. I do not see that there is any real difference between these two modes of branching. In both modes the parent stem divides into two branches, but in the one case both branches diverge from the line of the original stem, while in the other case one of the branches keeps on in the same direction as the parent stem and the other branch diverges from it. There is, however, another quite different kind of lateral branch which involves the distinction between terminal and lateral branching. At the growing end of a stem there are apparently a fixed number of immature thin-walled cells, of which the outer ones are in process of bending outward and taking on a thick-walled condition, and the inner ones are destined to grow forward, pass to the outer ring, and in their turn take on a mature condition and a radial direction. At certain periods, determined by conditions which no one has fathomed, the central group of cells is doubled, it divides into two diverging fascicles and a branch thus comes into being. In view of the fact that the axial portion of every stem is always thin-walled and the cortical portion always thick-walled, it is difficult to understand how branches can be given off in any other way, than at the ends of stems, yet specimens are found which have a young branch well down from any possible growing end. This condition might result from terminal branching in which one of the two off-shoots was much more vigorous than the other, but this explanation does not seem applicable to most of these cases. They can hardly be explained otherwise than by supposing either that in certain small areas of the mature stem the thick-walls of the cortical zone are resorbed and a young branch was proliferated, or else that similar areas remain thin-walled and immature for a certain period, prepared for such a contingency, being in fact latent branches. This hypothesis would account for the areas observed, for instance, on many specimens of *B. polyspinosa* characterized by having thin walls and numerous "mesopores" or young cells. An objection to both these explanations, however, is that it is not only a thickening of the walls by which the mature condition is characterized, but a development of acanthopores, granules, and sometimes mesopores, all of which are supposed to represent distinct and special kinds of zooids, the disappearance of which would be most difficult to account for.

Horizon and locality: Cherokee shale, station 255a. Henrietta formation—Ft. Scott limestone member, station 232 (?); Pawnee limestone member, station 204. Kansas City formation—Cherryvale shale member, stations 162, 210 (?), 644 (?); Iola limestone member, station 168 (?). Lansing formation—Lane shale member, stations 163, 285, 297 (?); Plattsburg limestone member, station 296. Douglas formation —Lawrence shale member, stations 208, 278 (?), 299 (?); Oread limestone member, stations 170, 284 (?). Shawnee formation—Calhoun shale member, station 197; Topeka limestone member, stations 179, 180, 200.

Batostomella sp. A.

Under this title I am including several distinct, though apparently connected, types. The first group comprises a few small, incrusting zooaria distinguished by the thinness of their walls and the large number of their mesopores (?). The incrustations are very thin, a mere film upon Composita or other forms. It is difficult to state the number of mesopores (?) even relatively as their distribution is irregular, but they are probably as numerous as the zooecia, if not more numerous. The walls are exceedingly thin, their tops smooth (when worn?) or armed with small granules. Normal acanthopores occur at some of the cell angles, but where present they are small.

A modification of this form is found at station 299. It appears to have the characters of the normal variety from which it differs in its appreciably finer structure.

In this group of specimens no branches are developed. The mode of growth is like *Tabulipora distans*, but the cells are shorter, the walls thinner, and the mesopores (?) more numerous; besides these there are other differences.

Another group of specimens shows what is provisionally considered to be a different stage of the same form. These also are incrusting. In a typical specimen of this group the walls are very thin in the outer parts of the zoarium, but toward the center they become thick and round the angles of the zooecia, and a slender stem, 1 mm. in diameter, which has similar thick walls and round zooecia, is given off. This specimen is in lot 300, and another like it is in lot 278.

A third group of specimens, chiefly from station 165, consist only of slender stems, 2 mm. in diameter or less. They resemble the stumps of stems that project from the basal expansion forming the group last described. These are slenderer than the stems of *B. greeniana* and have thinner walls. Similar stems occur in lot 221.

All of this material is rather scanty and ill adapted for sectioning; microscopic study or the examination of more and better material may show that these specimens do not belong together as they now seem to belong.

In some respects this form resembles *B. spinulosa*, but it has many mesopores (?) while *spinulosa* has few. Some specimens from station 170, though provisionally included under *Batostomella* sp. A. are more likely than the rest to belong to *B. spinulosa*. They occur as slender stems, 2 mm. in diameter arising from basal expansions, and are distinguished from the rest of the material by having fewer mesopores (?), and by other differences.

Horizon and locality: Cherokee shale—Bevier coal horizon, station 238. Henrietta formation—Ft. Scott limestone member, stations 262, 661, 667, 669. Douglas formation —Lawrence shale member, stations 278, 298, 299 (?), 300; Oread limestone member, station 170. Shawnee formation—Deer Creek limestone member, station 165(?); Calhoun shale member, station 187; Topeka limestone member, station 211. Wabaunsee formation—upper shale (Admire?), station 221.

Genus Tabulipora Young.

Tabulipora distans Condra.

1902. *Stenopora distans.* Condra, Am. Geol., vol. 30, p. 241, pl. 20, figs. 3-5.
Coal Measures: Louisville, Nebr.

1903. *Stenopora distans.* Condra, Nebraska Geol. Survey, Rept. vol. 2, pt. 1, p. 44, pl. 5, figs. 6-9.
Coal Measures: Louisville, South Bend, and LaPlatte, Nebr.

Only one specimen has been studied by thin sections and it, consequently, is the one upon which the identification chiefly rests. It is attached to a Composita and is only 20 millimeters across at the widest part. The thickness of the thin section is 1 millimeter but the maximum thickness of the specimen may be 2 millimeters. The walls are undoubtedly thicker in some places than in others but there are no distinct thick-walled areas. Similarly though the cells vary in size there are no distinct maculae nor though the surface is more or less uneven, are there distinct monticules. The zooecia are small near the margin of the zoarium, and over part of it they are conspicuously arranged in slightly decussating curved rows. They vary from strongly polygonal to sub-circular in section, according as the bounding walls vary from thick to thin. Here and there, one at a time, young cells occur among the large ones. Large acanthopores are a conspicuous feature of one end of the zoarium, but the other end, though apparently equally well preserved, scarcely shows them at all.

The thin sections show many of the characters mentioned above. In addition, they show that the cells attain a diameter of .28 millimeter, though most of them are .21 mm. or less. Six or seven occur in a linear distance of 2 mm. The walls are moderately thickened and in some the thickening is annular or periodic, but in most it is more or less uniform. Perforated diaphragms are abundant in most of the zooecia and they are as a rule considerably less than a cell diameter apart, but they may occur at much longer intervals. Large acanthopores are developed in some of the cell angles but are absent in many of them. Small acanthopores or granules also occur, forming rows along the median line of the walls.

In most particulars this form agrees closely with *T. distans*, but there are some differences. *T. distans* is said to have one-third as many mesopores as there are zooecia, while in my specimen the "mesopores" are distinctly less than one-third. Condra states that the walls of *distans* are not plainly moniliform, while the walls of my specimen in places plainly are. In my single rather poor tangential section some of the walls are thinner than any shown by Condra's figure, and the acanthopores are rather smaller and less numerous.

Horizon and locality: Cherokee shale—Mulky coal horizon, station 307. Henrietta formation—Ft. Scott limestone member, station 249; Pawnee limestone member, station 204. Kansas City formation—Chanute shale member, station 429a (?). Lansing formation—Plattsburg limestone member, stations 295 (?), 296. Douglas formation—Iatan limestone member, station 289 (?); Lawrence shale member, station 208 (?). Shawnee formation—Lecompton limestone member, station 288; Severy shale member, station 228.

Tabulipora vera n. sp.

Plate XXX, figures 9, 9a.

Zoarium in the form of irregular, more or less compressed stems, 7 mm. or less in diameter. Superficially the stems are seen to be made up of rather large zooecia with numerous small ones irregularly distributed among them. The small apertures, which are probably not of the nature of mesopores appear to be scarcely less numerous than the large zooecia, and are probably at least half as numerous. In some places the walls are thin, and the zooecia angular; in others the walls are much thicker and the zooecia rounded. Acanthopores are so few and small that the walls might at first be thought to be without them. Tangential sections show little more than this, save that the walls have distinct median lines made up of small granules.

The mature zone measures about 1 mm. or less. My observations on the thickening of the mature zone and on the diaphragms are somewhat at variance. It seems almost necessary to infer from the marked variation in thickness of the walls, as shown not only on the surface of the branches but in thin sections, that the thickening was moniliform, but my observations on this point, not very numerous it is true, would indicate that it was nearly uniform. Similarly, in one thin section the diaphragms are rather numerous—about a cell diameter apart—while in another specimen not sectioned, these structures appear to be absent. As many as six zooecia occur in 2 mm. or as few as 4½.

T. vera is distinguished by its ramose mode of growth, its numerous diaphragms, and its acanthopores, which are unusually few and small. Of described forms having the ramose mode of growth some differ so widely in other respects that a detailed comparison is not necessary. The most similar species is probably that described as *Stenopora polyspinosa*. *T. vera* differs, however, in having more numerous diaphragms, in having the walls more distinctly annulated, in having more numerous mesopores, and in having smaller acanthopores, of which the smaller sort are little more than an interrupted median line. I am now referring the other species to the genus Batostomella, but *T. vera* appears to be a true Tabulipora.

Horizon and locality: Kansas City formation—Bethany Falls limestone member, station 250.

Genus Liopora n. gen.

This genus grows in thin incrustations of small expanse and is composed of regularly arranged zooecia surrounded by abundant mesopores. Aggregations of numerous mesopores produce maculae which rise in low monticules. The cell structure is minute. Owing to the relatively thick walls, the zooecia and the much smaller mesopores are rounded. The walls are thickened in the mature region and irregularities in the deposit give them a distinctly moniliform appearance in sections which cut them longitudinally. The walls show no median line. Diaphragms are entirely absent, as are acanthopores and acanthopore-like granules. In many of the cells a slight projection springs from the bounding wall on one side (rarely more than one) as if showing the initial stage of fission, yet as none of the final stages are present, this interpretation seems inadmissible. A similar appearance is produced in some species by indenting acanthopores, but neither is this interpretation warranted by my observations in this case, for well-preserved surfaces show no projecting spines and thin sections show no differentiation in the walls such as usually indicates acanthopores or granules.

The position of this form seems to be among the Batostomellidae. In the infrequent yet still occasional thickening of the walls it suggests *Stenopora* but differs in almost all other characters, the minute size of the cells, the abundance of mesopores, and the absence of diaphragms and of acanthopores.

From typical Lioclema and from most of the variations of it at present included in the genus, it differs in the complete absence of diaphragms and of acanthopores, as well as, apparently, in the presence of the annular thickenings above mentioned. As figured by Ulrich, with numerous open mesopores and without acanthopores, his Kinderhook species *Lioclema wachsmuthi* is very much like the present type, but longitudinal sections of *L. wachsmuthi* show it to possess an abundant development of diaphragms, and Ulrich describes the apertures as surrounded by spinules (acanthopores), a feature not shown in his figures. The peculiar indentation of the zooecial tube possessed by this form is a character not found in any of the Batostomellidæ.

Liopora subnodosa n. sp.

Plate XXVII, figures 2, 2a; plate XXVIII, figures 1, 1a, 2, 2a.

Zoarium in the form of thin expansions attached to other organisms (chiefly *Composita subtilita*). All the colonies observed are small, under 25 mm. in diameter and under 1 millimeter in thickness, usually under .5 millimeter. Macroscopically the zoarium is seen to be made up of small sub-circular zooecia and numerous sub-circular mesopores. The mesopores are assembled at intervals into groups or maculae which are somewhat elevated and the zooecia adjacent to the maculae are of slightly larger size than the rest. The maculae stand at intervals of about 3.5 millimeters and an arrangement in rows is rather conspicuous. A linear arrangement of the zooecia is also striking.

In tangential section the zooecia are seen to be rounded but irregular, slightly lobate or petaloid. This results from two causes. One is that the walls, though thickened, are not sufficiently thickened completely to round the cells which are subangular in shape. The other cause is a peculiar structure, an angular projection of the wall indenting the cell on one side. This is not found in all the cells, but it occurs in too many of them to be accidental. The petaloid aperture produced in this way is so obvious that a hasty observer, without of course the aid of thin sections, might easily mistake this for a peculiar fistuliporoid. I am at a loss to interpret this structure. It at first suggests reproduction by fission, but not only are some of the cells without this projection of the walls, but none of them shows it carried beyond an initial stage, so that this interpretation seems untenable. Similarly, though acanthopores sometimes produce indentations of the cells resembling this, the walls in this form are conspicuously lacking in acanthopore structures. In diameter the zooecia measure from .14 to .17 millimeter in one section, from .17 to .21 in another, and are usually about their own diameter apart (.07 to .21 millimeter). Six, rarely 7, occur in a distance of 2 millimeters. In the vicinity of maculæ they are more widely separated. The mesopores are very much smaller though variable in size. They average about .07 millimeter in diameter, but many are smaller and some are larger, and they are disposed in one, or often two, rows between the zooecia; seldom three or more rows except near maculae. Like the zooecia they are more or less rounded, but they are more irregular than the zooecia in size and shape. Some are elongated with one diameter much greater than the other. The walls are rather thick for the diminutive cells which they divide. Those which separate the mesopores are indistinguishable from those which surround the zooecia, the whole making a network entirely uniform except for the size of the openings. In thickness they vary from .028 to .042 millimeter. They are entirely without traces of acanthopores.

Sections cutting the cells longitudinally show a series of tubes of large and small caliber, the former occurring singly, the latter mostly in groups of two or three (not infrequently singly, too). The mesopores originate close to the base of the zoarium showing a very narrow immature zone. Diaphragms are developed in neither zooecia nor mesopores. The walls are thickened soon after assuming an erect position, and the thickening is annular so that longitudinal sections show a moniliform structure.

Horizon and locality: Henrietta formation—Ft. Scott limestone member, stations 245, 251. Kansas City formation—Chanute shale member, station 429a. Douglas formation—Oread limestone member, station 273.

Genus Rhombopora Meek.

Rhombopora lepidodendroides Meek?

1866. *Stenopora columnaris* (pars). Geinitz, Carb. und Dyas in Nebraska, p. 66, (Not Schlotheim, 1813).
Upper Coal measures: Nebraska City, Bennetts Mill, and Wyoming, Nebr.

1872. *Rhombopora lepidodendroides.* Meek, U. S. Geol. Survey Nebraska, Final Rept., p. 141, pl. 7, figs. 2a-f.
Upper Coal Measures: Nebraska City, Bennetts Mill, Wyoming, Rock Bluff, and Plattsmouth, Nebr.; Kansas; Iowa; Missouri; Illinois.

?1877. *Rhombopora lepidodendroides.* White, U. S. Geog. Surveys W. 100th Mer., Rept., vol. 4, pt. 1, p. 99, pl. 6, figs. 5a-d.
Carboniferous: West face of Oquirrh Range, near "E. T. City," Utah, and at confluence of White Mountain and Black rivers, Arizona.

1884. *Rhombopora lepidodendroides.* Ulrich, Cincinnati Soc. Nat. Hist., Jour., vol. 7, p. 27, pl. 1, figs. 1-1b.
. Upper Coal Measures: Kansas City, Mo.; Nebraska City and Wyoming, Nebr.

1887. *Rhombopora lepidodendroides.* Foerste, Sci. Lab. Denison Univ., Bull., vol. 2, p. 73, pl. 7, figs. 3a, b.
Coal Measures: Flint Ridge and Bald Hill, Ohio.

1887. *Rhombopora* ————. Foerste, idem, p. 74, pl. 7, figs. 5a-c.
Coal Measures: Flint Ridge, Ohio.

1888. *Rhombopora lepidodendroides.* Keyes, Acad. Nat. Sci. Philadelphia, Proc., p. 225. (Date of imprint 1889).
Lower Coal Measures: Des Moines, Iowa.

1895. *Rhombopora lepidodendroides.* Keyes, Missouri Geol. Survey, Rept., vol. 5, p. 35, pl. 33, figs. 4a, b. (Date of imprint, 1894.)
Upper Coal Measures: Kansas City, Mo.

1896. *Rhombopora lepidodendroides.* Smith, Am. Phil. Soc. Proc., vol. 35, p. 237.
Upper Coal Measures: Poteau Mountain, Indian Territory.

1897. *Rhombopora lepidodendroides.* Smith, Leland Stanford Junior Univ. Pub.; Contrib. Biology, Hopkins Seaside Lab., No. 9, p. 27.
Upper Coal Measures: Poteau Mountain, Indian Territory.

1903. *Rhombopora lepidodendroides.* Girty, U. S. Geol. Survey Prof. Paper 16, p. 341.
Molas and Hermosa formations; San Juan region, Colo.
Weber formation: Leadville district, Colo.
Carboniferous: Grand River and Uinta Mountain regions, Colo.

1903. *Rhombopora lepidodendroides.* Condra, Nebraska Geol. Survey Rept., vol. 2, pt. 1, p. 99, pl. 6, figs. 2-4, pl. 7, figs. 1-12.
Coal Measures: Nebraska (20 localities).
Permian: Blue Springs and Wymore, Nebr.

1903. *Rhombopora lepidodendroides.* Condra, Am. Geologist, vol. 31, p. 22, pl. 2.
Permian: Numerous localities in Nebraska.
Permian: Kansas.

1906. *Rhombopora lepidodendroides.* Woodruff, Nebraska Geol. Survey, Rept., vol. 2, pt. 2, pl. 9, figs. 2-4.
Carboniferous: Nebraska.

?1908. *Rhombopora aff. R. lepidodendroides.* Girty, U. S. Geol. Survey, Prof. Paper 58, p. 153, pl. 31, fig. 17.
Delaware Mountain formation: Mountains northwest of Martahon, Texas.

Under this title are assembled many small specimens which may not belong to one species or even to one genus. All of them are small, mostly 1 millimeter or less in diameter, and regularly constructed, oblique ridges making rhombic openings which rapidly contract to an elliptical tube. The crests of the walls are furnished with a row of granules and their intersections with one or two large acanthopores. This is true of the most typical and the best preserved specimens but many are poor and fail to show all these characters. For this reason and because no thin sections have been made of any, the relations of these specimens are uncertain. Some of them may represent an immature condition of *Batostomella greeniana* var. *regularis* or, on the other hand, to that species may have been referred branches that really belong here.

One of these specimens found at station 658, preserves part of the basal expansion. The branch appears to be rather worn, as it shows thick walls which are flat on top, and elliptical zooecia without vestibula, and the same characters appear in the basal portion. Young cells are not present in either.

Horizon and locality: Cherokee shale—stations 255, 307 (?) 708, 1268C1. Henrietta formation—Ft. Scott limestone member, stations 247, 256, 661, 674. Pleasanton formation, station 231 (?). Kansas City formation—Hertha limestone member, station 233; Chanute shale member, stations 168, 173 (?), 416 (?). Lansing formation—Lane shale member, stations 658, 677; Stanton limestone member, stations 305 (?), 691 (?). Douglas formation—Weston shale member stations 297 (?), 301 (?); Iatan limestone member, station 304 (?); Lawrence shale member, stations 208 (?) 300; Oread limestone member, stations, 178, 181 (?), 292. Shawnee formation—Calhoun shale, station 188; Topeka limestone member, stations 179, 211; Severy shale member, station 212. Wabaunsee formation—upper limestone (Emporia?) station 226.

Genus Productus Sowerby.

The genus Productus is peculiarly characteristic of the Carboniferous. No other type has shown such great diversity of form and ornamentation combined with such close repetition of established structural characters. In the Carboniferous faunas of nearly every country the genus has accumulated such a number of species that some sort of reclassification is desirable if only from the standpoint of utility. Certain types more or less conspicuously Productoid have indeed been taken out and set up as distinct genera so that we have Marginifera, Tegulifera, Strophalosia, Aulosteges, and a few others, some of which have been on the border line between acceptance as genera and rejection as of subordinate rank. Yet under Productus itself a very large number of species still remain, vastly more than those that have been taken away. Various authors have sought relief in assembling these species into groups, using some well marked species as the center of each group, but the same groups were not recognized by different authors, nor were the groups given names such as could be employed in our binominal nomenclature. Thus, when a species of Productus was mentioned, one still had to be familiar with that particular species in order to have more than a very general conception of the appearance and character of the shell referred to.

In a recent monographic study of the British Carboniferous Producti[1] Dr. Ivor Thomas has sought to establish a sub-division of the old genus Productus on lines differing somewhat from those of other attempts. He makes only a few groups and bases them chiefly on external characters and their development, and he gives the groups generic names. In so far as these new groups are based on superficial rather than on structural characters it seems to me that they are perhaps a little less satisfactory than other brachiopod genera, though it is true that some other genera such as Composita, Cliothyridina, and Athyris are on much the same basis. The main point about Dr. Thomas's classification is how it will work. If the correct position of most species is not fairly obvious so that they are referred by different authors to different genera, the confusion arising will be worse than our present troubles. I propose in this place to try to distribute our American species of Productus among Dr. Thomas's generic units, but a failure to do so satisfactorily does not indicate the failure of his classification as judged by the test of practicability, for many assignments must necessarily be made on insufficient data, the data of description and figures alone, or even descriptions alone, and sometimes poor descriptions and poor figures.

In his classification of the Producti Dr. Thomas recognizes seven genera as follows: Productus Sowerby, 1814; Avonia gen. nov.; Pustula gen. nov.; Buxtonia gen. nov., Overtonia gen. nov., Proboscidella Oehlert, 1887; Etheridgina Oehlert, 1887. His classification is immediately framed, be it remembered, for British species and apparently for only such species as have been included in the genus Productus. Some of these types either do not occur in the American faunas or have been recognized as representing distinct genera, so that only four of Dr. Thomas's groups are really concerned in a revision of our American Producti. These with their generic diagnoses summarized from Dr. Thomas's work are as follows:

Productus: forms that are costate throughout all stages of growth; sporadic spines or even groups or rows of spines may appear on the costae[2] or intersections of costae and ribs (where the semireticulate feature is developed on the visceral part of the shell surface). Several phyletic series are probably present in this group representing distinct subsections.

Avonia: forms which are spinose in the early stages but develop costae at a later period.

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[1]Thomas, Ivor, Geol. Survey Great Britain, Memoirs, Paleontology, vol. 1, pt. 4, pp. 197-366, 1914.

[2]After considering several terms Dr. Thomas decides to use "costae" for the longitudinal ridges, and "ribs" for the transverse ridges, where such occur.

Pustula: forms which are essentially spinose in ornamentation.

Buxtonia: forms characterized in the young and adult stages by a costate and spinose ornamentation, but in old age developing the spinosity alone.

Overtonia, which is based on internal peculiarities of the brachial valve, may exist in our faunas but as internal structures are seldom seen and still more seldom figured, its presence must be left for future determination. The following list of American Producti, including a few from South and Central America, does not comprise all of the species that have been found, merely those that have been described as new or have been cited in such manner as to be included in bibliographies.

Productus adairensis.
" æquicostatus
" alternatus=Pustula alternata
" altonensis
" americanus
" arcuatus=Avonia acuata
" arkansanus=Avonia arkansana (possibly Pustula)
" arkansanus var. multiliratus=Avonia arkansana var. multilirata
" arseneaui=Productus ? arseneaui (diductor scars peculiar)
" auriculatus
" auriculispina
" batesianus
" biseriatus=Pustula biseriata
" blairi=Avonia blairi
" boliviensis
" boonensis
" boonensis var. elevata
" borealis
" buchianus=Pustula buchiana
" burlingtonensis
" calhounianus
" calhounianus var. kansasensis
" capacii—suggests the genus Marginifera
" carbonarius
" chandlessii
" cherokeensis=Productus inflatus
" clarkianus
" compressus
" confragosus
" cora
" cora var. mogoyoni
" coriformis=Productus pileiformis
" costatoides—suggests the genus Marginifer
" costatus
" curtirostris=Pustula (possibly Productella) curtirostris
" dawsoni
" dawsoni var. acadicus
" delawarii
" depressus
" dolorosus=Pustula (possibly Productella) dolorosa
" doubleti
" duplicostatus
" eucharis
" fentonensis
" fernglenensis

Productus fimbriatus = Pustula fimbriata
" flexistria
" gallatinensis
" geniculatus
" giganteus
" gracilis
" gradatus
" granulosus = Pustula granulosa
" guadalupensis
" guadalupensis var. comancheanus
" hepar—probably invalid
" hildrethanus
" humboldti = Pustula humboldti
" inca
" incurvus
" indentatus
" indianensis = Pustula indianensis
" inflatus
" inflatus var. clydensis
" inflatus var. coloradoensis
" insinuatus
" ivesi
" levicosta
" latidorsatus = Pustula latidorsata
" latissimus
" leei
" leplayi
" leuchtenbergensis = Pustula leuchtenbergensis
" limbatus
" lineolatus
" longus
" magnicostatus
" magnus
" margaritaceus
" marginicinctus
" martini
" meekanus = Pustula meekana
" mesialis
" mesolobus = Pustula mesoloba
" mexicanus
" montpelierensis = Pustula montpelierensis
" moorefieldanus = Pustula moorefieldana
" moorefieldanus var. pusillus = Pustula moorefieldana var. pusilla
" morbillianus = Buxtonia (possibly Pustula) morbilliana
" multistriatus
" nebraskensis = Pustula nebraskensis
" nevadensis = Pustula nevadensis
" newberryi = Avonia newberryi
" newberryi var. annosus = Avonia newberryi var. annosa
" nodicostatus
" nodosus
" norwoodi = Pustula norwoodi
" occidentalis
" ovatus
" papilio

Productus parvicostatus
" parviformis
" parvulus
" parvus
" pectinoides—probably invalid
" pertenuis
" peruvianus = Pustula peruviana
" phillipsi—suggests the genus Diaphragmus
" phosphaticus
" pileiformis
" pileolus = Pustula pileola
" pinniformis
" pocillum—probably invalid
" popei
" popei var. opimus
" portlockianus
" prouti
" punctatus = Pustula semipunctata
" pustulosus = Pustula pustulosa
" pyxidiformis = Pustula ? pyxidiformis
" raricostatus
" reticulatus
" rhomianus—suggests the genus Strophalosia
" rushvillensis
" sampsoni
" scabriculus = Buxtonia scabricula
" scitulus
" semireticulatus
" semireticulatus var. arcticus
" semireticulatus var. capitanensis
" semireticulatus var. hermosanus
" semireticulatus var. kansasensis
" semistriatus—possibly a new genus
" setiger
" setiger var. keokuk
" signatus = Pustula ? signata
" spinosus—probably invalid
" subhorridus = Pustula ? subhorrida
" subhorridus var. rugatulus = Pustula subhorrida var. rugatula
" subserratus—suggests the genus Marginifera
" subsulcatus = Pustula subsulcata
" subsulcatus var. janus = Pustula subsulcata var. janus
" swallowi = Pustula ? swallowi
" symmetricus = Pustula symmetrica
" tenuicostiformis
" tenuicosta
" texanus
" undifer
" verneuilianus = Pustula verneuiliana
" villiersi
" viminalis—suggests the genus Productella
" vittatus = Pustula vittata
" waagenianus
" wallacianus = Pustula wallaciana
" walcottianus = Avonia ? walcottiana

Products weyprechti
" wilberanus = Pustula wilberana
" winchelli = Pustula winchelli
" wortheni

The foregoing list contains the astonishing number of more than 150 species and varieties, most of which occur in the United States, though a few names are introduced from the Arctic region, from Canada, and from South America. Some synonyms have already been eliminated; a few others are suggested here and still others will doubtless be discovered as work progresses. It is to be doubted, however, whether new species will not be found much more rapidly than old ones are discarded as synonyms. It should also be remembered in considering the differentiation of this genus in the western hemisphere that the list does not include foreign species which have been merely cited without accompaniment of descriptions or figures.

It will be seen from a scrutiny of the list that the great majority of species still remains under Productus ss. Pustula receives most of those removed in the present classification, namely:

Pustula alternata
" biseriata
" buchiana
" ? curtirostris
" ? dolorosa
" fimbriata
" granulosa
" humboldti
" indianensis
" latidorsata
" leuchtenburgensis
" ? meekana
" mesolobus
" montpelierensis
" moorefieldana
" " var. pusilla
" nebraskensis
" nevadensis
norwoodi
" peruviana
" pileola
" semipunctata
" pustulosa
" ? pyxidiformis
" ? signata
" ? subhorrida
" ? subhorrida var. rugatula
" subsulcata
" subsulcata—var. janus
" ? swallowi
" symmetrica
" verneuiliana
" vittata
" wallaciana
" wilberana
" winchelli

Avonia receives:
Avonia arcuata
Avonia? arkansana
Avonia? arkansana var. multilirata
Avonia? blairi
" newberryi
" newberryi var. annosa
" ? walcottiana
and Buxtonia receives:
Buxtonia ? morbilliana
" scabricula

On the basis of the genera introduced by Dr. Thomas, a possibly new genus will be found in *Productus semistriatus* which like Buxtonia has the early portion costate but the later portion not spinose but smooth.

I would say again that the grouping offered here is preliminary. Some of the assignments will doubtless have to be changed when more is known of the species or when our conception of the genera becomes more defined. Several species left under Productus ss. will probably be transferred to Avonia. According to my observations a number of species, Mississippian species especially, though regularly costate over most of their surface have the visceral region for a greater or less distance marked by discontinuous costæ terminating in small spines. This character would apparently bring such species under the genus Avonia, but if the spinose region were very small, they would probably best be held under Productus. It is doubtful whether a sharp boundary can be drawn between these two genera.

In Pustula Dr. Thomas seems to include not only shells that have numerous spines but shells that have only a few spines provided that they are not marked by radial costæ. In his classification, based so largely, as it is, on sculptural features, he does not provide for species possessing cardinal or hinge teeth, and it may be presumed that his specimens do not show these structures. Indeed, he suggests that *Productus sinuatus*, which possesses an area and a delthyrium may form the nucleus of a new genus, and probably if Productella occurred in England he would have included it in his classification as a distinct genus. Many of our American Productellas would from their superficial characters belong in Dr. Thomas's Pustula and since the determining characters of Productella are rarely shown and the status of many species is consequently uncertain, it is likely that some of the Mississippian types here placed with Pustula may prove to belong with Productella, and that some of the species at present cited under Productella and not considered here for that reason will prove to belong under Pustula.

As yet no American shells can be referred definitely to Overtonia but some of the dubious Productellas, especially when their internal characters are studied more carefully, may find place in that genus. One American species, *Productella pyxidata*, in some of its phases strikingly resembles *Overtonia fimbriata*, the type of Overtonia. So far as yet known the resemblance is only superficial. (Compare, however, Fig. 34 of Pl. 17, Geol. Survey of New York, Paleontology, vol. 8, pt. 1, 1891 which shows oblique brachial ridges comparable to those of *O. fimbriata*.)

Genus Pustula Thomas.

Pustula semipunctata Say.

Dr. Thomas has given an accurate description and figures of typical *Productus* (*Pustula*) *punctatus* as it occurs in the British faunas. If these are used as a starting point and if the same care is employed in discriminating species that was employed by Dr. Thomas, it becomes highly probable that the American form or forms so long known as *Productus punctatus* can no longer be referred to the British species. Dr. Thomas himself mentions several differences (p. 309), as that the European species clearly differs in the bilobate character of the inner face of the cardinal process, and that White's figure is quite distinct from Martin's form, both in general shape and ornamentation. "The concentric bands are more riblike and are each ornamented only by one row of spine bases, while the shell is more drawn out longitudinally." White's figure is probably inexact in showing but a single row of spines in each of the concentric bands, for all of the specimens that I have seen show several rows. The American forms, however, are characterized, many of them even more strongly than in White's figure, by the elongated shape by which they are strikingly distinguished from typical *Pustula punctata.*

If we conclude therefore, as seems necessary, that the American form or forms found in the Pennsylvanian (for the Mississippian shells may possibly belong to a still different species), are not identical with *Pustula punctata* as now limited, a new name must be sought for them. That first introduced is *Productus semipunctatus* Say, and although Say's description and figure are extremely inadequate, there can be really little doubt of the form he intended to designate. If, however, more careful investigation proves that the Pennsylvanian faunas of the Mississippi Valley contain several species of this type, then indeed it would be difficult to say to which the name *Pustula semipunctata* should apply.

Horizon and locality: Cherokee shale, stations 266, 307a. Henrietta formation—Ft. Scott limestone member, station 707. Pleasanton formation, station 236a. Kansas City formation—Hertha limestone member, station 233; Drum limestone member, station 415; Iola limestone member, station 182. Lansing formation—Plattsburg limestone member, stations 185, 659; Stanton limestone member, stations 277, 290a. Douglas formation—Oread limestone member, stations 178, 273. Shawnee formation—Deer Creek limestone member, station 165; Topeka limestone member, station 200.

Genus Marginifera Waagen.

Marginifera muricata var. missouriensis n. var.

Plate XXX, figures 2-2b, 3-3b, 4, 4a, 5, 5a.

At certain localities in the Cherokee shale a small Productoid apparently belonging to the genus Marginifera occurs in great abundance. In its specific characters it resembles *M. muricata* but differs constantly in several ways so as to warrant recognizing it as a distinct variety. It is small and in shape subquadrate, marked by fine, regular costae which are crossed over the visceral region by fine, more or less strong and irregular transverse wrinkles. Numerous small spines spring from the costæ and from the ears.

From typical *M. muricata* this shell is distinguished by its small size and less transverse shape. The costæ are finer and more regular and there is no trace of a sinus, a character sometimes faintly developed in the other species. On the contrary some ventral valves have the median part of the anterior prolongation raised into a sort of ill-defined fold, though I believe not as a constant feature.

This variety resembles the Colorado shell described as *M. ingrata* in the fineness of its costæ, but it has more numerous spines and a less transverse shape and it also lacks the sinus of *M. ingrata.* Although in my description of the latter species it is stated to be without a median sinus, both of the typical specimens show this feature in a slight degree though possibly as a result of compression. The present form suggests also *Marginifera? nana* but if the simultaneous bifurcation of the costæ upon which Meek lays stress is a constant feature in that species, that constitutes a signal difference. Furthermore, I judge from Meek's figure that *M. ? nana* has coarser costæ.

Horizon and locality: Cherokee shale, stations 1263 A3 (?), 1263 B4, 1263 C1, 1263 C3, 1263 C3+.

Genus Ambocoelia Hall.

Ambocoelia lobata n. sp.

Plate XXX, figures 1-1d.

Shell rather large for the genus, sub-pentagonal in outline, transverse, widest just below the cardinal angles, which are rounded.

The ventral valve is strongly convex, inflated in the median portion, abruptly descending to the sides which are, however, more or less projecting and lobate. A flattening along the median line or a very faint sinus appears to be present. The beak is not as prominent and high as in some species of the genus. The cardinal area is narrow and rather poorly defined from the inflected sides.

Dorsal valve very transverse, moderately convex, with a distinct median sinus toward the front and with two lateral sinuses which give this valve a four-lobed shape. The umbonal region is rather inflated for the genus with a small incurved beak. The two lateral sinuses cause the lateral outlines to be broadly reentrant and the median sinus joined with the faint sinus on the opposite valve produces a shallow, though abrupt, notch in the anterior outline, all adding to the peculiar lobate appearance of the shell.

Surface smooth or covered by minute spines.

If this is an Ambocœlia the lobate configuration and the convexity of the dorsal valve distinguish it from our common Pennsylvanian species. Although I have but a single specimen, the differences are too marked for this to be merely an abnormal individual of *A. planiconvexa.*

The generic position of this shell is in some doubt as it is not without suggestions of Squamularia. Its internal structures are unknown and I have referred it to Ambocoelia chiefly because of the surface which does not show the scars of relatively large spines regularly arranged in concentric rows, but instead, if not to all appearance entirely smooth, shows traces of very minute spines thickly set without any observable order.

Horizon and locality: Shawnee formation—Lecompton limestone member, station 183.

Genus Leda Schumacher.

Leda arata Hall.

Plate XXXI, figures 1-8.

1852. *Nucula arata.* Hall, Stansbury's Expl. Surv. Gt. Salt Lake, Utah[1], p. 413 pl. 2, figs. 5a, b.
Carboniferous: Missouri River below Weston.

1899. *Nuculana arata.* Girty, U. S. Geol. Survey, Nineteenth Ann. Rept., pt. 3, p. 581.
Upper Coal Measures: McAlester quadrangle, Atoka quadrangle, Okla.

Though first described in 1852, this species has only once subsequently appeared in paleontologic literature. It is nevertheless extremely abundant at several localities in the Leavenworth quadrangle near the base of the Lawrence shale and I am inclined to think that it has sometimes been confused with the well-known *Leda bellistriata.* It is, however, distinguished by conspicuous differences from that species, or at least from the common acceptance of that species for, if critically considered, *Leda bellistriata*

[1]Of this work there are several editions. The first appears to have been printed in Philadelphia in 1852 by order of the Senate; a second was printed in 1853 by the Public Printer in Washington, by order of the House of Representatives; a third was printed in Philadelphia in 1855 apparently as an independent venture All three editions are essentially identical.

can scarcely be said to be well and authentically established; it rests more on Hall's work than on Stevens's. Of the correct identification of the present specimens with *L. arata* there can hardly be a doubt. They come from essentially the same locality and horizon as Hall's type and agree with his description.

Hall's type specimen was fragmentary and also much smaller than some of those which have come under my observation. His description runs as follows:

"*Nucula arata.* Shell oval-ovate, rounded before, and gradually narrowing behind the beaks (posterior extremity broken off); beaks prominent, closely incurved; posterior lunule elongated and distinctly defined; surface marked by distinct (rather sharp where unworn) equal concentric ridges, scarcely so wide as the furrows between them. The ridges, when seen in a longitudinal direction, have an imbricated appearance."[1]

The abundant material which I have been fortunate enough to obtain enables me to make certain additions to the characters set down by Hall. The species attains a large size for the genus, some specimens having a width of 34 millimeters. The convexity is high but many specimens contract rapidly behind, both in height and in thickness, giving the posterior extremity an attenuated, nasute appearance. The escutcheon is sharply defined and deeply depressed. This structure is itself beveled along the hinge by a rather large ligamental area which in most specimens is distinct and sharply defined and in many is continued under the beaks, reappearing on the anterior side. Altogether this receptacle for the external ligament seems to occupy about half the hinge length.

The sculpture is relatively coarse and consists of unsymmetrical ridges which have the short abrupt slope on the upper and the long gradual slope on the lower side. In some specimens the ridges are more or less irregular toward the posterior end where several may unite in one and they die down to mere growth lines near the shoulder that defines the escutcheon.

My specimens show the internal characters very incompletely. I am unable to give the number of hinge teeth which they possess, the most important character observed being a definite and rather large chondrophore shown by both of the specimens which expose this portion of the hinge.

Writing of *L. bellistriata* Stevens in 1858 (the year that saw the publication of the paper by Stevens who may have communicated specimens to Hall), Hall states that it differs from *L. arata* in having the beaks more abruptly elevated, the escutcheon less strongly marked and the concentric striæ much finer. These differences hold when tested by my abundant material. In my experience *L. bellistriata* is usually a much smaller species than this but some authors, as for instance White, have figured specimens as large as the largest of mine and have identified them with *L. bellistriata*, a circumstance which makes me somewhat mistrust the identification. Aside from size the most striking difference between the two species is the much coarser sculpture of *L. arata*. Hall has also called attention to the less prominent umbones of the latter species which has at the same time a more sharply and deeply depressed as well as a flatter escutcheon. The specimens of *L. bellistriata* which I have recently figured from the Wewoka formation of Oklahoma represent about the average in my experience and are only about half the size of large specimens of *L. arata*. Young specimens of the latter, comparable in size to mature *L. bellistriata*, are more transverse, with the beak slightly more posterior and the posterior extremity much more produced and also with the sculpture conspicuously coarser.

Horizon and locality: Henrietta formation—Pawnee limestone member, station 1266A2. Kansas City formation—Drum limestone member, station 429 (?). Lansing formation—Lane shale member, stations 189, 657; Plattsburg limestone member, stations 296 (?), 682; Stanton limestone member, station 290a. Douglas formation—Lawrence shale member, stations 207, 208, 276a, 276b, 283, 298, 299, 300.

[1]Hall, James, Stansbury's expedition to the Great Salt Lake, 1852, p. 413.

Genus Conocardium Bronn.

Conocardium missouriensis n. sp. (P. V. Roundy Mss.)

Plate XXVIII, figures 3-3c.

Shell small; length but little greater than the height. Beaks small, projecting slightly above the hinge line and apparently anchylosed. Hiatus very wide and long. The valves contract more rapidly on the posterior than on the anterior side of the umbonal ridge. The posterior margin forms practically a straight line from the end of the ridge to the hinge line, while anteriorly the line is slightly sinuous (convex below and concave above) to the (broken) alate portion. This naturally gives a much greater prominence to the anterior part of the shell than is usual in the Carboniferous members of this genus. The umbonal ridge itself is well defined and has six small nodes. These may be varices of growth or an inherent character of the species. They are somewhat irregularly spaced, which would suggest the former view, yet the absence of similar nodes or other prominent growth characters on the remainder of the shell would point to their being a specific character. Anterior to the ridge there are 8 strong, well-rounded ribs, with interspaces somewhat wider than the ribs. No evidence of concentric sculpture is visible on this part of the shell. The alate anterior end has been broken off so that it is not possible to determine the characters of this extremity.

On the posterior side the sculpture consists of about 11 very fine, radiating costae, the interspaces increasing in width to the posterior end (there are two more costae on the left valve than on the right). The costæ are crossed by somewhat finer and more closely arranged liræ which extend to the front edge of the umbonal ridge. Twenty-five of these liræ can be counted on each valve. They probably originally numbered about 30. Dimensions: height 5.5 millimeters; greatest length 6 millimeters.

This species more closely resembles the Mississippian species *C. prattenianum* than any of the described Pennsylvanian forms. It differs in having a larger part of the shell anterior to the umbonal ridge and in having a greater number of ribs on this part. The ribs on the posterior part of the shell are not as strong as in *C. prattenianum*, while the liræ crossing them are but little weaker than the ribs themselves and show no traces of extending over onto the anterior part as in the latter species. This description is based upon a single specimen.

Horizon and locality: Kansas City formation—Drum limestone member, station 429.

Genus Lima Bruguiere.

Lima gregaria Meek and Worthen.

1870. *Monotis? gregaria.* Meek and Worthen, Acad. Nat. Sci. Philadelphia Proc., p. 38.
Coal Measures: Jacksonville, Ill.

1873. *Monotis? gregaria.* Meek and Worthen, Geol. Survey Illinois, Rept. vol. 5, p. 573, pl. 26, fig. 5.
Coal Measures: Jacksonville, Ill.

1895. *Monotis? gregaria.* Keyes, Missouri Geol. Survey, Rept. vol. 5, p. 114. (Date of imprint 1894.)
Upper Coal Measures: Kansas City, Mo.

Shell small, subovate. Valves with a rather strong obliquity, presumably backward. Hinge length rather more than half the greatest width. Outline straight above on the posterior side and directed obliquely backward, very full and rounding outward on the anterior side. Convexity high, the posterior side planate and strongly descending, the anterior descent broader and more arching.

Surface marked by elevated radial lines which are separated by relatively wide flattened interspaces and are more or less irregularly distributed, occurring sometimes singly, sometimes in groups of 2, 3, or 4. They cease abruptly toward the posterior side, the flattened posterior slope being entirely without them. Toward the anterior side they die down gradually and the anterior half of the shell may be nearly smooth or marked wholly or in part by radii which are very obscure, or at least less distinct than the median ones. On this account the present species, if correctly placed with the Limidae, may probably be included in the sub-genus Plagiostoma.

Lima gregaria occurs at station 1254 B-1 where it is associated with *Cardiomorpha missouriensis*, with abundant Goniatites (chiefly, however, in larval stages), and with a few other forms, constituting a fauna not elsewhere found in the collection. I have also obtained what is almost certainly the same species from a horizon that is supposed to be approximately the same at Fort Scott, Kansas, in black shaly beds above the cement rock.

I feel little doubt that this is the species described by Meek and Worthen as *Monotis? gregaria*. Their specimens were flattened in shale and more or less distorted and they did not show the high convexity which is found in some of the present specimens preserved in a limestone matrix. Although referring this form provisionally to Monotis, Meek and Worthen suggested that it might possibly be a true Lima, in which genus, partly on account of the high convexity and other features in the configuration, I have thought best to place it. The chief objection to this reference seems to lie in the tenuity of the shell, a character which influenced Meek and Worthen in assigning it to Monotis.

Horizon and locality: Cherokee shale—Mulky coal horizon, station 435 (?). Henrietta formation—Ft. Scott limestone member, stations 666, 1266 A 1.

Genus Astartella Hall.

Astartella compacta n. sp.

Plate XXVIII, figures 4, 4a, 5, 5a.

Shell small, transverse, subquadrate. Extreme width ¾ to 4/5 the height. Hinge line straight, about two-thirds of the entire width, parallel to the basal outline. The latter rounds upward about equally at either end. At the front an inflection of the shell produces an emargination below the beak and causes the anterior extremity to have a pointed shape. On the posterior side the outline above the well-rounded posterior-inferior angle is nearly straight and it meets the hinge in a distinct angle of somewhat more than 90°. The convexity is rather high, the beaks large and incurved. The surface is marked by numerous regular, closely arranged, concentric lamellæ.

The generic characters of this species have not been observed and the generic reference is based upon a number of minor points of configuration, the pointed anterior extremity with a more or less sharply defined lunule above, the distinct posterior cardinal angle, and the somewhat upturned cardinal line. Although the shape and closely arranged sculpture are not without suggestions of Edmondia the characters mentioned indicate rather clearly, without however proving the point, that the generic relations are with Astartella.

A. compacta is distinguished from all the American species known to me by the close arrangement of the concentric lamellæ and it is distinguished from most of them also by its compact form which is unusually high for the width and which does not contract posteriorly.

Horizon and locality: Cherokee formation, stations 435, 1268A2.

Genus Pleurotomaria Sowerby.

Pleurotomaria? persimplex n. sp.

Plate XXXII, figures 1-1d, 2, 2a.

Shell small, subdiscoidal, composed of 4 or 5 volutions; height nearly twice the width; spire low; volutions somewhat transverse in section, regularly rounded; sutures depressed; umbilicus small and shallow. Band rather broad, peripheral, on a level with the general curvature and consequently somewhat obscure, but defined by delicate depressed lines and by the curvature of the incremental striæ.

The surface is without revolving ornamentation, and entirely smooth save for obscure growth lines, which pass somewhat obliquely across the shell with a strong and fairly abrupt reentrant angle at the band. The general direction of the growth lines and the profile of the aperture is obliquely backward from the suture down, or obliquely forward from the umbilicus up, with the exception that the lower part of the outer lip has for a short distance from its contact with the preceding volution a backward instead of a forward direction. It then turns rather sharply forward as above described, thus producing a slight sinus.

These shells might carelessly be referred to several species from which they are really quite different. One of these is *Anomphalus rotulus*, but besides certain specific characters such as the higher spire, the more deeply incised sutures, etc., *P.? persimplex* is at once distinguished by the presence of an unmistakable slit band. Rather similar also is *Pleurotomaria? valvatiformis* as shown by Meek and Worthen's figures, but the resemblance diminishes with the recognition of the fact that the present form is four times as large and clearly lacks the revolving liræ which mark, though obscurely, the other species.

I know of no other species in our Carboniferous rocks which is really closely allied to *P.? persimplex*. In fact, it seems not improbable that this will form a nucleus of a new genus when the Pleurotomarias are classified, the distinguishing characters being the smooth surface and the small though distinct sinus on the posterior side of the aperture.

Horizon and locality: Cherokee shale, station 1268A2.

Genus Murchisonia D'Archiac and De Verneuil.

Murchisonia missouriensis n. sp.

Plate XXX, figures 6, 6a.

Shell in the shape of a flat-based cone, elongate, tapering, consisting of about 13 volutions. Length 14 mm., diameter 6 mm. The lateral and basal surfaces of the volutions are nearly plane, especially the lateral surface, and make an angle between them of somewhat more than 90°. The angle which they would thus form, however, is truncated by two strong carinæ, the upper rather more prominent than the lower, and the intervening groove wider than either. The lateral surface of the volution is divided into three nearly equal zones by a pair of elevated revolving lines between which, rather than between the carinæ, the slit band appears to lie. A faint revolving lira also is developed upon the basal surface some distance from the carina. The volutions overlap up to the lower carina and usually with such precision that this carina is not apparent except on the last volution. Lines of growth are almost invisible.

This species resembles *Goniospira lasallensis*. It is, however, a more rapidly expanding shell and is also smaller when composed of the same number of volutions. Furthermore, the slit band is situated on the lateral surface instead of between the two edges of the carina, as it is in *G. lasallensis*, which has no revolving lines on the lateral surface. Somewhat similar differences of sculpture distinguish *M. missouriensis* also from *M. archimedea* which is a larger and more rapidly expanding species.

Horizon and locality: Cherokee shale, station 1268 A2.

Genus Goniospira n. gen.

Of this genus *Murchisonia lasallensis* is taken as the type. The shape is long, slender, and many-whorled, 17 or 18 volutions being found in the type species. The volutions are more or less rhombic in section with a submedian carina, both above and below which the shell is flattened. The sutures are strongly reentrant and the shell as whole has a screw-like appearance. The slit band is situated on the periphery just below the angular carina, which forms its upper boundary. The character of the slit is not certain but it appears to be deep, about ⅓ of a volution in length. As determined by the lines of growth the aperture slopes forward from the slit on both the upper and lower surfaces, gently forward above the slit and strongly forward below it. The surface is almost smooth aside from growth lines of varying strength. The shell above the carina is devoid of spiral markings in the type species, but a pair of revolving ridges is developed about midway on the lower surface which simulate a slit band. The axis is solid. An inner lip is apparently present, the deposit continuing out on to the columellar portion of the outer lip which appears thickened and as if reflexed.

This type is clearly distinct from Murchisonia as based on *M. coronata*, nor is it a typical Pleurotomaria. It resembles Whitfield's genus Lophospira more than any with which I am acquainted. From Lophospira, however, it differs in having a long slit(?) instead of a mere notch, in having a solid columella and in other characters.

A small number of Pennsylvanian species resemble *G. lasallensis* in a general way so closely as to suggest that they belong to the same genus, but they differ in important details. *Murchisonia archimedea*, a less slender species than *M. lasallensis*, may belong in Goniospira, but it is described as so to leave in doubt the position of the slit band and other significant characters. *Murchisonia buttersi*, a species much more nearly like *G. lasallensis* in shape, has revolving liræ, costæ transverse to the volutions, and a slit band situated on the periphery instead of just below it. Furthermore, the band is marked by revolving liræ and by nodes. These differences appear to me to be generic and the name Helicospira is suggested for this species. *Murchisonia collingsworthensis* has a shape more like *M. archimedea* and the band is not peripheral but situated on the upper surface. *M. gouldii* is somewhat comparable to *G. lasallensis* in shape but the slit band lies well above the carina and the surface is marked by revolving liræ. Very similar in a general way is *M. terebra*, but *M. terebra* is marked by revolving lines and has the carina nodulose. The position of the band is not given. *M. terebra* appears to be especially related to *H. buttersi.*

Goniospira lasallensis Worthen.

Plate XXX, figures 7, 8, 8a.

1890. *Murchisonia lasallensis.* Worthen, Geol. Survey Illinois, Rept., vol. 8, p. 141, pl. 25, figs. 7, 7a.
Upper Coal Measures: Lasalle, Ill.

1903. *Worthenia? lasallensis?* Girty, U. S. Geol. Survey, Prof. Paper 16, p. 457.
Hermosa formation: San Juan region, Colo.

This species is rather abundant in several collections and though my fossils almost certainly belong to Worthen's species, they show his description to be at fault in several particulars. The size attained is greater than that indicated by his figures, some specimens having a diameter of 10 mm. in the largest volution. My large specimens are incomplete at the apical end and my small ones incomplete by growth or by breakage at the apertural end. Some of the small specimens look as if they might belong to a small slender variety of the large ones. Nevertheless, when one of the small fragments representing the apical half is placed above one of the large fragments representing the apertural half, no discrepancy is apparent between the rate of increase of either the spire or of the volutions. The smaller specimen has a length of 11 mm. and a diameter at the base of 4½ mm. It consists of 12 volutions. The larger fragment has a diameter below of 10 mm. (where it is still incomplete), a length of 20 mm., and it contains 5 volutions. If the measurements of these two specimens may be combined, a fairly large specimen would consist of 16 or 17 volutions, and it would have a length of 31 mm. with a diameter at the aperture of 10 mm.

Worthen states that on the last volution there is a flattened band below the carina which is bounded below by a slight elevation and that this feature does not extend to the other volutions. These statements are incorrect in several particulars, for the site of the slit-band is the carina itself and the structure which Worthen mistakenly identifies as the slit band does extend to the other volutions. The carina is in fact accompanied by a somewhat smaller but still rather prominent ridge and between the two is the real locus of the slit band. The second ridge is situated below the carina than which it is not only smaller but also, springing from the inward-sloping surface, less prominent. Worthen apparently overlooked the duplicate character of the carina and mistook for the slit band the similar pair of ridges that are situated half way, or rather more than half way down the lower side of the volution. Like the carina and its fellow the upper ridge of the second pair is larger and more prominent than the lower but the false slit band is rather narrower than the true one. As to the identification of the slit band and its position on the periphery there can be no doubt. My specimens show the growth lines (which are rather strong and fasciculate) traversing the upper side of the volution, straight, or very slightly sigmoidal, and with a gentle backward obliquity from the suture to the carina, near which they are strongly inflexed. Below the carina the growth lines, strong here as above it, are distinctly curved, convex toward the aperture and strongly oblique from the carina forward. They cross the pair of ridges that lie midway on the lower surface without deflection and terminate at the ridge just below the carina with a backward swing. The deeply concave surface between this ridge and the carina is marked by lunate growth lines concave toward the aperture. Furthermore, one specimen which retains the aperture in fairly complete condition seems actually to show the slit at this position. It is deep and extends backward about ⅓ of a volution. This, however, is somewhat doubtful as the present condition may be due or partly due to breakage.

By Worthen's statement that the false slit band does not extend to the higher volution one must of course understand him to mean that it is concealed on them, but even this is not entirely true. Normally, I believe, the suture is aligned with precision so as to fall on the upper of the two revolving ridges that comprise this structure. In some specimens, however, the alignment is not so precise and the upper ridge, together with more or less of the sulcus below it, are exposed. It may be that on some specimens both ridges are visible but I have not observed this.

There is some inconsistency in my observations on the character of the aperture. That the shell has a solid axis there can be no doubt. Some specimens indicate the presence of an inner lip, others do not. Those that show this structure at all show the lower part of the outer lip to be thickened as if by a doubling back of the shell on itself. I suspect that there was an inner lip of which this duplication of the shell is a continuation and that the deposit may sometimes be thin as upon those specimens upon which it now seems to be absent, or that it may be developed only within the aperture or may in some way have been obscured.

Horizon and locality: Lansing formation—Lane shale member, stations 189, 657; Plattsburg limestone member, station 682; Stanton limestone member, station 290a. Douglas formation—Lawrence shale member, stations 205, 208, 276b, 283, 298, 299, 300.

Genus Naticopsis Mc Coy.

Naticopsis nana Meek and Worthen.

1860. *Platyostoma nana.* Meek and Worthen, Acad. Nat. Sci. Philadelphia, Proc., p. 463. (Whole volume dated 1861.)
Upper Coal Measures; Springfield, Ill.
1861. *Naticopsis nana.* Meek and Worthen, Acad. Nat. Sci. Philadelphia, Proc., p. 148. (Whole volume dated 1862.)
1866. *Naticopsis nana.* Meek and Worthen, Geol. Surv. Illinois, Rept., vol. 2, p. 365, pl. 31, figs. 4a, b.
Upper Coal Measures: Springfield, Ill.
1875. *Naticopsis nana.* White, U. S. Geog. Surv. W. 100th Mer., Rept., vol. 4, pt. 1, p. 159, pl. 12, figs. 4a, b. (Whole volume published in 1877.)
Carboniferous: Camp Cottonwood, near Spring Mountain, Lincoln County, Nev.
1884. *Naticopsis nana.* White, Dept. Geol. Nat. Hist. Indiana, 13th Rept., pt. 2, p. 162, pl. 36, figs. 6, 7.
Middle and Upper Coal Measures: Indiana.
1888. *Naticopsis nana.* Herrick, Sci. Lab. Denison Univ., Bull. vol. 4, pl. 11, fig. 8.
Coal Measures: Fultonham, Ohio.
1891. *Naticopsis nana.* Keyes, Acad. Nat. Sci. Philadelphia, Proc., p. 257 (Whole volume dated 1892).
Lower Coal Measures: Des Moines, Iowa.
1895. *Strophostylus nana.* Keyes, Missouri Geol. Survey, Rept., vol. 5, p. 196. (Date of imprint, 1894.)
Upper Coal Measures: Clinton and Kansas City, Mo.
1896. *Naticopsis nana.* Smith, Am. Phil. Soc., Proc., vol. 35, p. 250.
Upper Coal Measures: Sebastian County, Ark.
1897. *Naticopsis nana.* Smith, Leland Stanford Junior Univ. Pub., Cont. Biol. Hopkins Seaside Lab., No. 9, p. 40. (Printed also with same date and pagination, but with a different cover and title page as a reprint of the Proc. Am. Phil. Soc. which in fact both are.)
Upper Coal Measures: Sebastian County, Ark.
1903. *Strophostylus cf. nanus.* Girty, Prof. Paper U. S. Geol. Survey, No. 16, p. 462.
Carboniferous: Glenwood Springs, Colo.

There are certain small shells in the collections which, though so differently shaped and ornamented, appear to be only young specimens of *Naticopsis altonensis*, but they might readily be mistaken for *N. nana* or a kindred form. They have, however, a higher spire and somewhat differently shaped volutions. I have one specimen nevertheless from the same collection which appears to be a true example of *N. nana*, for it has a lower spire and more flat-topped and compressed volutions. It is rather smaller than Meek and Worthen's type specimen but not greatly so.

Horizon and locality: Cherokee shale, station 1268A2. Douglas formation—Weston shale member, station 301; Oread limestone member, station 219 (?).

Naticopsis scintilla n. sp.

Plate XXIX, figures 3-3c.

Shell very small, composed of 2 or 3 rapidly expanding volutions; greatest length somewhat in excess of the greatest width. Spire rising but little above the last volution which is much elongated and strongly oblique. This volution is somewhat depressed or broadly sulcate on the upper surface just below the suture, which gives the shell to some extent the shape of *N. altonensis* and its allies. It probably belongs to the *altonensis* group, but those species when as small as this are very different.

The surface is marked by fine striæ of growth and by somewhat stronger striæ at regular intervals. The umbilicus is closed and a distinct callosity is developed.

In its small size this species suggests *Naticopsis* (or *Strophostylus*) *nana*. It is, however, not only much smaller but the volutions are differently shaped being much more elongated in section and having the broad sulcus just below the suture. As regards its size two other specimens from the same locality are no larger than the type, so that this must be considered a mature form.

Horizon and locality: Kansas City formation—Drum limestone member, station 429.

Genus Naticella Munster.

Naticella americana n. sp.

Plate XXXII, figures 3-3c.

Shell small, subglobose, comprising 4 or 5 rapidly enlarging volutions. Greatest width slightly exceeding the greatest height. Volutions regularly and strongly rounded. Sutures deeply incised. Surface marked by thin prominent costæ, regularly arranged at moderately wide intervals, in the deep grooves between which occur more or less irregular and unequal growth lines.

The only American species inviting comparison with this is *Naticella transversa* from the Permian Red Beds. The present species is clearly distinct being larger, more high-spired, and somewhat more coarsely costate. My specimens indicate, though they do not show clearly, that the early stages of *Trachydomia wheeleri* bear a strong resemblance to this species, the superficial nodes which are characteristic of Trachydomia arising by interuptions in the transverse ridges that are developed in the immature stage. When of the same size, however, *T. wheeleri* appears to have had its peculiar, or at all events a different sculpture, so that I feel fairly confident that the present is a distinct species. The resemblance, nevertheless, raises a question of generic position, which I am at present unable to settle.

Horizon and locality: Cherokee shale, station 1268 A2.

Genus Zygopleura Koken.

Zygopleura affinis n. sp.

Plate XXXII, figures 6-6b.

The best specimen of this form is 8 mm. long and 3 mm. in diameter and consists of about 11 volutions. The whorls are somewhat flat-sided with the lower portion more strongly rounded so that the sutures, though distinct, are not deep. The plications are strong, about 15 in number on the largest whorl and they extend from suture to suture ending rather abruptly at the peripheral line, the lower portion of the final whorl being smooth.

This species is most nearly allied to *Z. plicata* but differs in several respects. The shape is not so slender nor the size so large, the specimen described having about 11 volutions at a length of 8 mm. while the type of *Z. plicata* has the same number of volutions at a length of 19 mm. The plications also appear to be more numerous for the size of the shell though actually my example has the same number which is given by Whitfield for his much larger specimen. Similar differences are shown when this form is compared with an associated specimen which has been identified as *Z. plicata* instead of with Whitfield's description and figures.

Horizon and locality: Cherokee shale, station 1268 A2.

Zygopleura nana n. sp.

Plate XXXII, figures 5-5a.

Shell small, conical, one mm. in diameter and rather less than 3 millimeters long, composed of 6 or 7 volutions. Volutions rather high, flattened at the sides and abruptly rounding below, embracing so far as to leave but a shallow suture and give the shell as a whole a smooth conical shape. The rate of increase in the size of the whorls is greater, however, in the younger than in the older stages which renders the shape somewhat fusiform. The aperture is small, oval. The axis is solid. The sides are marked by rather large, rather strong, longitudinal plications, about 14 to a volution.

This species is most closely allied to *Z. rugosa* and perhaps it might be considered only a dwarfed variety of it, especially as most of the associated species are small. Aside, however, from being only one-third as large, though composed of the same number of volutions, the volutions are relatively higher with flatter sides and shallower sutures and the plications are less numerous.

Horizon and locality: Kansas City formation—Drum limestone member, station 429.

Zygopleura nodosa n. sp.

Plate XXXII, figures 10, 11, 11a

Shell large, turreted, composed of about 7 volutions. A large fragmentary specimen has the final whorl 18 mm. in width and it must have had a length of 45 mm. or more. The volutions are rhombic in outline. The surface above the periphery is somewhat concave, that below the periphery gently convex, the two meeting in an angle somewhat greater than 90 degrees. The periphery is strongly rounded and marked by a row of oblique, elongated nodes or pilae, of which about 17 occur on one of the larger volutions. They end rather abruptly at the peripheral line and die down more gradually above, being traceable about one-third the distance to the suture. Above and below the nodose zone the surface appears to be smooth, the growth lines which were probably present at one time having been lost. The nodes are somewhat elongated and somewhat oblique, the upper end being posterior to the lower. They are separated by grooves of about their own width. It is probably due to this band of prominences that the shell appears concave below the suture. The axial portion of the outer lip is apparently reflexed so as to form a slender columella but the reflexed lip is narrow and bounded by a sulcus.

This shell is probably a Zygopleura but is quite distinct from other species in the American Carboniferous, not only by reason of its larger size but by reason of the deep suture and the limitation of the plications to the peripheral region so that they appear more like nodes than elongated costae. No other species is comparable to this in size except *Z. plena* which, however, is larger, while the flattened side and deeper suture together with the shorter, larger plications distinguish *Z. nodosa* not only from *Z. cara* but from all other American species yet described.

Horizon and locality: Shawnee formation—Calhoun shale, station 206.

Zygopleura teres n. sp.

Plate XXXII, figures 4, 4a.

Shell small, tapering, composed of 7 or 8 volutions. Length 3½ millimeters, diameter 1½ millimeters. The volutions are short with rather flat sides, strongly rounded below. They embrace so far as to leave a distinct though not deep suture, and the outline is therefore nearly smooth. The immature volutions increase in size more rapidly than the mature ones, so that the apical portion tends to be conical and the lower portion cylindrical, and a somewhat fusiform shape is produced. The aperture is small, oval. The axis is solid.

The surface is marked by fine incremental lines parallel to the axis, which are gathered at regular intervals into fascicles or obscure plications.

The foregoing description is based upon the typical specimen. A second specimen is at hand indicating a considerably larger size (2 millimeters in diameter), but it is fragmentary and I am not sure that it belongs to the same species.

Z. teres is distinguished by its minute size, its fusiform shape, its slightly indented sutures, and its obscure corrugations. In one or all of these particulars it differs from other American species so that more detailed comparisons are not necessary. Indeed, the species is somewhat doubtfully referred to Zygopleura at all and would perhaps better be placed under Pseudomelània. It resembles *Z. nana*, but is less distinctly corrugated. This is not well shown in the figures; the shading which in this species suggests corrugations, appears in fact to represent color markings.

Horizon and locality: Kansas City formation—Drum limestone member, station 429.

Subgenus Hemizyga n. subgen.

In a peculiar phase of the fauna of the Cherokee shale there occurs a group of species which can not be included under Zygopleura without unwarrantably enlarging the scope of that genus, yet whose relationship to the Zygopleuras associated with them is so obvious that it seems doubtful whether they consititute an entirely distinct and independent genus.

They pass, in brief, through a Zygopleura stage that comprises the major portion of the shell. At a certain stage which occurs earlier in some forms and later in others, the characteristic longitudinal ridges of Zygopleura subside into growth lines of which the ridges may be considered fascicles, and a series of revolving striæ is introduced, a feature which is quite alien to true Zygopleura. In one species an intermediate condition exists, the coarse plications of typical Zygopleura giving place to much finer markings such as are also found in forms referred to Zygopleura, but these in turn are succeeded by the final stage in which the revolving striæ are developed. In one particular the statements made above involve an inference rather than a direct observation, for since the revolving liræ are confined to the lower moiety of the volution, which is fully exposed only in the final whorl, it can not be positively asserted that they are a late development rather than a continuous feature of the individual. That it is a late, possibly a gerontic, character seems probable from the close resemblance of the early stages to Zygopleura, in which such markings are not found, and from the modified condition of the Zygopleura characters in the final volution, on which alone these spiral striæ have actually been observed.

There may be some question whether these shells should not be referred to the Triassic gènera Heterocosmia or Acrocosmia. One well marked and important difference from Heterocosmia is the fact that in the latter the revolving striæ cover the entire shell instead of being confined as here to the later volutions and to the lower portion of those. Acrocosmia differs in having a very brief instead of a very long Zygopleura stage and in having the volutions flat-sided and flat-bottomed instead of rounded.

It seems probable that the forms which in a recent paper Miss Mark doubtfully referred to the genus Aclisina (*A.? cancellata*, *A.? costata*, and *A.? ornata*) may find place in this group.

Hemizyga dubia n. sp.

Plate XXXII, figures 9-9b.

Shell small, conical, composed of 9 or 10 volutions. Length 10 mm., diameter of the final volution 4.5 mm. Volutions transverse in cross section with well rounded sides and somewhat flattened base. Sutures deep.

Surface marked as in Zygopleura by strong, regular plications, transverse to the volutions but longitudinal to the shell as a whole. The plications in this species are of equal size throughout, though tending on the last half whorl to become indistinct or obsolete. There are about 42 of these on the last volution where they are distinct enough to be readily counted. On this volution there are also traces of obscure revolving costæ, coarse and distinct on the sides, fine and indistinct underneath.

The spiral markings in this species, of which but a single specimen has been obtained, are not perhaps distinct and regular enough to remove them definitely from the category of the accidental. If this form is a Zygopleura, the shallow, well-rounded volutions and the fine costæ will serve to distinguish it from associated species, of which *Z. multicostata* is perhaps the nearest.

In some respects this species resembles *Aclisina? cancellata* Mark, but it is a much larger shell and the plications are oblique in the opposite direction.

Horizon and locality: Cherokee shale, station 1268 A2.

Hemizyga elegans n. sp.

Plate XXXII, figures 7-7b.

Shell small, conical, consisting of 8 volutions; length 7.5 mm., diameter 4 mm. Volutions rather rapidly expanding, elongated in cross section and somewhat flattened above so that the peripheral line is below the center. Suture fairly deep.

The surface is marked in the young stages by strong plications longitudinal to the shell as a whole, which are replaced on the last turn and a half by much finer, though sharp and regular, liræ having a similar direction. These are less distinct on the lower part of the last volution where, instead, the surface is crossed by a large number of more or less wavy, unequal, crowded, revolving liræ of which traces can be detected on some of the foregoing volutions, though the volutions embrace up to about the line where the revolving liræ cease so that they would be for the most part concealed.

Horizon and locality: Cherokee shale, station 1268A2.

Hemizyga grandicostata n. sp.

Plate XXXII, figures 8-8b.

Shell small, conical, composed of 7 or 8 volutions. Height 9.5 mm., diameter of last whorl 4.5 mm. Volutions rather strongly and regularly rounded. Suture deep.

Surface marked by strong plications which on the last whorl become somewhat finer and distinctly fainter, subsiding and disintegrating into rather strong growth lines on the lower half, where they are crossed by numerous fine distinct revolving liræ, which are stronger and more conspicuous than the transverse markings.

This species is distinguished from *H. elegans* most obviously by its much coarser plications. It is a more rapidly expanding shell than *H. dubia* and with more distinct revolving liræ.

Horizon and locality: Cherokee shale, station 1268A2.

Genus Bulimorpha Whitfield.

Bulimorpha minuta Stevens.

Plate XXIX, figures 4-4b.

1858. *Loxonema minuta.* Stevens, Am. Jour. Sci., sec. ser., vol. 25, p. 260.
Coal Measures: Sangamon County, and Danville, Ill.

?1913. *Bulimorpha minuta.* Mark, Geol. Surv., Ohio, Bull. 17, fourth ser., p. 317, pl. 16, fig. 15. (Date of imprint, 1912.)
Portersville limestone: Portersville, Ohio.

Entirely apart from questions of nomenclature, a subject which is itself considerably involved, it will probably always be difficult to refer specimens to the genera Soleniscus, Sphærodoma, Bulimorpha, etc., because the only characters upon which reliance can be placed are not very striking, nor are they shown in the usual conditions of preservation.

Associated with naticoid and loxonematoid forms in the interesting gastropod facies of the Cherokee fauna, there occur a number of small fusiform shells which probably are better referred to Bulimorpha than to Soleniscus or Sphærodoma, since they show no indication of folds on the axis. As in most gastropod groups where specific distinctions have to be made on differences in shape, often of no very great degree, and where the specimens are apt to be incomplete at the apex or at the aperture, I have found it far easier to select certain well marked types and identify them, than to assign the intermediate or less perfect specimens. Thus in the collection to which these remarks chiefly apply one specimen closely resembles *Bulimorpha chrysalis* and is referred to that species with such confidence as is possible without the advantage of comparison with authentic or typical examples. Another specimen agrees nicely with *B. inornata*, if indeed Meek and Worthen's species may be placed in the genus Bulimorpha. Another type is represented by some small, elongate shells, tapering almost equally at both ends. They are more slender than *B. chrysalis* and are considerably smaller, though composed of an equal or even greater number of volutions.

The specific identification of this type is not easy. It is not as far removed taxonomically as it is geologically from the Mississippian species *B. bulimiformis*. Though the largest specimens included here are distinctly larger, this form appears to be quite similar to Stevens' poorly described and unfigured *Loxonema minuta* in so far as it is possible to arrive at an idea of that species from the characters given.

Possibly a fourth form is found in some specimens (when imperfect not always readily separated from the group last mentioned) whose distinguishing characteristic is, however, the shorter final whorl and the correspondingly higher spire. Provisionally, however, these have been included under *B. inornata*, although the most characteristic specimen of the latter is much larger.

Stevens' characterization of *Loxonema minuta*, unaccompanied as it is by figures, has proved so inadequate that different authors have referred to it quite different types of shells. From his known care as a worker, from his opportunities as a contemporary of Stevens, and from the source of his material which was Danville, Ill., the same as that of typical *L. minuta*, Meek may be supposed to have identified this species correctly in 1873, yet his figures show a form differently proportioned in several respects.

Stevens does not mention the shoulder or angulation which produces a horizontal platform just below the suture, a feature distinctly shown by Meek's figures, and he gives the length of *B. minuta* as exactly four times the height whereas Meek's figure shows it to be 2.4 times. Meek's shell was apparently a different and less slender species. Keyes though discussing *B. minuta* no less than three times, does not figure it nor fully describe it; apparently he based his identification on Meek's and was dealing with the same species. Meek referred *Loxonema minuta* to Actæonina, Keyes to Bulimorpha, but as Meek's form (and probably Keyes') possesses the angulation below the suture which characterizes the genus Macrochilina (if, indeed, that feature is an important character), I prefer to cite it under Macrochilina, and as it seems to be distinct from typical *Loxonema minuta*, I propose to call it *Macrochilina? danvillensis*.

Miss Mark has recently used the name *Bulimorpha minuta* (Stevens) for a minute shell from Ohio. As shown by her figures, however, this is different alike from typical *Loxonema minuta* and from the form figured by Meek. It is even more gibbous than Meek's species, the height being only about 1.8 times the diameter (instead of 4 times as in the typical specimen); it lacks the angulation of Meek's species, and it is much smaller than either.

My own attempt to recognize Stevens' species has more to commend it than either of those mentioned. My form is well nigh as slender as is demanded by Stevens' description, and agrees with it in most other particulars. The specimen which I figure, however, is larger than that on which Stevens based his description and there are other still larger specimens referred to the same species.

Horizon and locality: Cherokee shale, station 1268 A2. Kansas City formation—Drum limestone member, station 429. Douglas formation—Iatan limestone member, station 289.

Genus Goniloboceras Hyatt.

Gonioloboceras parrishi Miller and Gurley?

1894. *Goniatites sp.?* Keyes, Missouri Geol. Survey, Rept., vol. 5, pl. 56, fig. 1.
Upper Coal Measures: Missouri.

1896. *Goniatites parrishi.* Miller and Gurley, Illinois State Mus. Nat. Hist., Bull. No. 11, p. 36, pl. 4, figs. 6-8.
Upper Coal Measures: Kansas City, Mo.

1900. *Milleroceras parrishi.* Hyatt, in Zittel's Textbook of Paleontology, American Ed., Cephalopoda, p. 550.

1903. *Milleroceras parrishi.* Smith, U. S. Geol. Survey, Mon. 42, p. 127, pl. 16, figs. 6-8.
Upper Coal Measures: Kansas City, Mo.

The fine black limestone at station 1254 B is crowded with Goniatites, most of them evidently very immature (since they have a diameter of only 1 or 2 millimeters or less). A few, however, are larger and of more nearly mature growth. Two quite distinct types are represented by these specimens and there may be others. One type has a strongly evolute growth and has been identified with considerable confidence as *Gastrioceras welleri:* the other, which is highly involute, is less perfectly known and is referred, though not with any certainty, to *Milleroceras parrishi.* This reference is entirely on the strength of a certain external resemblance, for the suture and consequently the generic position are unknown.

Horizon and locality: Henrietta formation—Ft. Scott limestone member, station 1254 B.

Genus Gastrioceras Hyatt.

Gastrioceras welleri Smith.

1903. *Gastrioceras welleri.* Smith, U. S. Geol. Survey, Mon. 42, p. 98, pl. 24, figs. 13-20.
Des Moines formation: Carroll County, Mo.

It is probable that the specimens here under consideration belong to the species named above, but if so they must be regarded as only half-grown individuals, save for a fragment which indicates an original size about equal to that of the types. Aside from this, a few specimens have a diameter of 11 millimeters or less, while a great number of very small shells have a diameter of 1 millimeter more or less, and probably represent the earliest stages of the same species. The larger specimens (11 millimeters in diameter) consist of 6 or 7 gradually enlarging, very evolute whorls which are transversely elongated in cross section and rather flat on the venter which is, however, more highly arched in the last whorl. The umbilicus is broad and deep. The surface on the internal mold is marked by rather fine, faint, regular, transverse striæ. A part of the shell is preserved on the large fragment mentioned above and shows regular, transverse imbrications. None of my specimens shows the suture.

Horizon and locality: Cherokee shale, station 1263C1. Henrietta formation—Ft. Scott limestone member, station 1254B.

Register of Localities.

162. West center sec. 16, T. 61, R. 29. Up branch ½ mile west of Little Sampson Creek, Cherryvale shale member of Kansas City formation.

163. On road, southeast corner sec. 30, T. 52, R. 31. From shale below Broadhead's 108. Upper part of Lane shale member of Lansing formation.

164. Same as 217, at the point between Turkey Creek and the Kaw, at Kansas City, Mo. Cherryvale shale member of Kansas City formation.

165. Broadhead's 186. East central part of sec. 30, T. 59, R. 37, on high point between creek and Missouri River bottom. Deer Creek limestone member of Shawnee formation.
166. On west side of creek near east side of sec. 5, T. 58, R. 29. South of township line. Northern extension of Iola limestone member of Kansas City formation.
167. N.W. ¼ N.W. ¼ sec. 29, T.62, R. 26, where road crosses branch. Top of Cherryvale shale member of Kansas City formation.
168. Quarry on creek north of Burlington R. R., just east of Caldwell-DeKalb line. Limestone in Chanute shale member of Kansas City formation.
169. Broadhead's 150. In extreme northeast corner sec. 29, T. 59, R. 36. Main ledge of Oread limestone member of Douglas formation.
170. Quarry in bluff, between two creeks, east side of sec. 27, T. 59, R. 36. Broadhead's 152. Stringer above main ledge of Oread limestone member of Douglas formation.
171. On road west of creek, sec. 7, T. 51, R. 32. Below Broadhead's 100. Lane shale member of Lansing formation.
172. Broadhead's 91. Second cut south of Elmira. Chanute shale member of Kansas City formation, just above Cement City limestone bed.
173. On the east side of Milwaukee R. R. South of trestle in N.E. portion of sec. 3, T. 54, R. 29. Raytown limestone bed, in Chanute shale member of Kansas City formation.
174. One mile north of Liberty in cut on Milwaukee R. R. Cement City limestone bed (?), in Chanute shale member of Kansas City formation.
175. In ravine north of station 209. Henrietta formation (upper part).
176. In creek northwest of cross roads $\frac{14 \mid 13}{23 \mid 24}$, T. 52, R. 32. Broadhead's 95. Chanute shale member of Kansas City formation, between Raytown and Cement City limestone beds.
177. Broadhead's 150. In ravine on north side Burlington R. R. on line $\frac{19}{30}$, T. 59, R. 35. Main ledge of Oread limestone member of Douglas formation.
178. Broadhead's 150. Near center of Atwood and Newell's quarry at Amazonia. Main ledge of Oread limestone member of Douglas formation.
179. One hundred feet northwest of bridge over Kinsey Creek, in extreme southern part of sec. 18, T. 60, R. 38. In shale between Broadhead's 197 and 199? Topeka limestone member of Shawnee formation.
180. Thirty-six to forty feet above Deer Creek limestone at the big quarry below Curzon. Topeka limestone member of Shawnee formation.
181. Quarry in Broadhead's 150. East of center of sec. 19, T. 58, R. 35. On Missouri River bluffs. Main ledge of Oread limestone member of Douglas formation.
182. Same as station 168. Iola limestone member of Kansas City formation.
183. In bed of creek, north central part of sec. 11, T. 59, R. 37. Upper layer of Lecompton limestone member of Shawnee formation.
184. Extreme northwest corner of sec. 7, T. 55, R. 36. In Broadhead's 143? South bank of Rushville Creek. Lower part of Oread limestone member of Douglas formation.
185. In ravine on east side of sec. 2, T. 51, R. 35. Broadhead's 108 at foot of bluff. Plattsburg limestone member of Lansing formation.
186. S.W. ¼ S.E. ¼ sec. 20, T. 59, R. 29, Broadhead's No. 111. Shale below main ledge of Stanton limestone member of Lansing formation.
187. West of Stahl, south side of Job's Branch, just above mouth. Summit coal, 25 feet below top of Cherokee shale.
188. Just east of line 23|24, T. 59, R. 38. On Missouri River bluffs. Limestone lens in Calhoun shale member of Shawnee formation.

189. Road east of creek. East part of sec. 6, T. 51, R. 32. Upper part of Lane shale member of Lansing formation.
190. Broadhead's No. 92, on Milwaukee R. R. one mile south of Bement, Clay County. Chanute shale member of Kansas City formation, between Raytown and Cement City limestone beds.
191. Big quarry below Curzon. Broadhead's limestone 186. Deer Creek limestone member of Shawnee formation.
192. West side of sec. 6, T. 59, R. 15. Near old railroad grade of Iowa and St. L. R. R. Cherokee shale, 30-40 feet below top Mulky or Summit coal horizon.
193. East side Rush Creek, 1¼ miles north of Liberty, west of Milwaukee R. R. Shale above Broadhead's No. 85d. Cherryvale member of Kansas City formation.
194. Quarry on west side of Burlington R. R., 1¼ miles north of Liberty. Shale above 85a. Cherryvale shale member of Kansas City formation.
195. Broadhead's 90. South of road, east of creek, in sec. 4, T. 51, R. 32. Cement City limestone bed in Chanute shale member of Kansas City formation.
196. Same as 166. Iola limestone member of Kansas City formation.
197. Quarry at Forest City. Shale between layers of Broadhead's 192. Calhoun shale member of Shawnee formation.
198. On Burlington railroad, 3 miles south of Quitman. Topeka limestone member of Shawnee formation.
199. Same as 198. Broadhead's 209. Topeka limestone member of Shawnee formation.
200. Broadhead's 197-199. Same as 197. Topeka limestone member of Shawnee formation.
201. Quarry west of Trenton, Mo. Bethany Falls limestone member of Kansas City formation.
202. Road side just west of house of J. M. Davis near southeast corner of sec. 28, T. 58, R. 24. Limestone (probably equivalent to Altamont limestone in Kansas). Pleasanton formation.
203. Cap rock in Powersville coal mine. Henrietta formation, probably in the Fort Scott limestone member.
204. East side of Grand River, 200 yards north of south line of sec. 21, T. 58, R. 24. Pawnee limestone member of Henrietta formation.
205. Shaly limestone near base of Lawrence shale member of Douglas formation, 10-15 feet above Broadhead's No. 121. Missouri River bluff 1 mile northeast Kenmoor, Buchanan County.
206. S.W. ¼ N.W. ¼ sec. 9, T. 59, R. 37. Broadhead's 192, above bridge. Limestone lens in Calhoun shale member of Shawnee formation.
207. Gully in N.W. ¼ sec. 33, T. 36, R. 54, where road leads up to house. Near base of Lawrence shale member of Douglas formation.
208. Shaly limestone near base of Lawrence shale member of Douglas formation, 10-15 feet above Broadhead's No. 121. Missouri River bluffs at shale pit of Phoenix Brick Co., St. Joseph, Mo.
209. At 81.3 mile post on Q. O. & K. C. R. R., east of Stahl. Summit coal, 25 feet below top of Cherokee shale.
210. On south side of Little Otter Creek, 100 paces east of road on line between secs. 19 and 20, T. 57, R. 27. Cherryvale shale member of Kansas City formation.
211. Broadhead's 209. South of railroad bridge over Nodaway River in N.W. ¼ sec. 16, T. 63, R. 37. Topeka limestone member of Shawnee formation.
212. Between river and railroad track in N.W. ¼ sec. 9, T. 64, R. 37. Top of Severy shale member of Shawnee formation, just under Howard limestone member.
213. Broadhead's limestone 137. South side of gully in north-central part of S.W. ¼ sec. 30, T. 56, R. 36. Amazonia limestone bed, in Lawrence shale member of Douglas formation.

214. Broadhead's No. 150. On point of hill, sec. 20, T. 54, R. 36. Main ledge of Oread limestone member of Douglas formation.
215. Iola limestone member of Kansas City formation, along Cliff Drive at Kansas City, Mo.
216. First cut west of Gee Creek on C. R. I. and P. R. R. between Hickory Creek and Jamesport. Cherryvale shale member of Kansas City formation.
217. Quindaro, Kansas. Broadhead's 85-c. Cherryvale shale member of Kansas City formation, just above base.
218. Tarkio limestone member of Wabaunsee formation. McKissick's Grove, Fremont County, Iowa.
219. In quarry in Broadhead's 150. N.E. ¼ sec. 36, T. 59, R. 36. Main ledge of Oread limestone member of Douglas formation.
220. Same as 218. Cap rock of Nyman coal, 25 feet above Tarkio member of Wabaunsee formation.
221. Shale pit at Nebraska City, Neb. Limestone layer in shale in Wabaunsee formation.
222. In gully in saddle between 2 outliers of Broadhead's 186 on bluff of Missouri valley near line between secs. 30 and 29, T. 59, R. 37. Upper layer of Lecompton limestone member of Shawnee formation.
223. Broadhead's 209 in ravine trending southeast in N.E. ¼ N.W. ¼ sec. 24, T. 59, R. 38. Toepka limestone member of Shawnee formation.
224. Broadhead's 160-166. South-central part of sec. 19, T. 59, R. 35, in excavation on divide. Lecompton limestone member of Shawnee formation.
225. Same as 178. From Broadhead's 146 (upper part). Shale between lower and middle limestones of Oread limestone member of Douglas formation.
226. Shale pit at Nebraska City, Neb. Limestone in Wabaunsee formation.
227. Broadhead's 160-166. In center of N.W. ¼ sec. 25, T. 59, R. 36. Lecompton limestone member of Shawnee formation.
228. Near center of sec. 32, T. 60, R. 38. Severy shale member of Shawnee formation, just below Howard limestone member.
229. Upper part of Broadhead's 186 in hollow near center N.E. ¼ sec. 23, T. 59, R. 38. Deer Creek limestone member of Shawnee formation.
230. Shaft of John Keynon. N.W. ¼ N.W. ¼ sec. 8, T. 53, R. 21. Bevier coal, about 100 feet below top of Cherokee shale.
231. In old strip pit, ¾ mile south of north line of sec. 5. East side of section where road turns east. T. 39, R. 33. Pleasanton formation, in shale that corresponds to Bandera shale of Kansas.
232. Locust Creek, sec. 7, T. 61, R. 20, Sullivan County. Fort Scott limestone member of Henrietta formation.
233. Broadhead's 74. Railroad cut southeast part Milan, Sullivan Co. Hertha limestone member of Kansas City formation.
234. Railroad cut on Santa Fe just west of bridge over Mussel Fork. Fort Scott limestone member of Henrietta formation.
235. Southwest corner of sec. 33, T. 40, R. 33. West side of road, south side of creek. Pawnee limestone member of Henrietta formation.
236. Strip pit north of road in sec. 33, T. 40, R. 33. Pleasanton formation, in shale that corresponds to Bandera shale of Kansas.
236a. Same as 236. Pleasanton formation, in shale that corresponds to Bandera shale of Kansas.
237. In strip pit, southeast corner sec. 8, T. 40, R. 31. Pleasanton formation, in limestone that corresponds to Altamont limestone of Kansas.
238. T. 60, R. 21 where line between secs. 23 and 26 crosses creek. Bevier sump rock in east bank of creek. Cherokee shale, 100 feet below top.
239. Strip pit in northeast corner sec. 25, T. 40, R. 29. Lower limestone of Fort Scott limestone member of Henrietta formation.

240. In mound northwest of Monteith Junction. Upper limestone of Fort Scott limestone member of Henrietta formation.
241. Limestone in road $\frac{28}{33} \big| \frac{27}{34}$, T. 46, R. 24, south of Knobnoster. Cherokee shale, upper part.
242. S.E. ¼ sec. 13, T. 38, R. 32, in bed of creek crossing road. Cherokee shale, about 75 feet below Fort Scott limestone member of Henrietta formation.
243. Old cut, S.E. ¼ N.E. ¼ sec. 34, T. 39, R. 32. Lower limestone of Fort Scott limestone member of Henrietta formation.
244. In road, in middle of sec. 12, T. 57, R. 19. Near west side of section. Concretions in shale over Mulky coal. Cherokee shale, 35-40 feet below top, Mulky coal horizon.
245. N.E. ¼ S.W. ¼ sec. 31, T. 58, R. 22. Bank Medicine Creek, Collier's Mill. Fort Scott limestone member of Henrietta formation.
246. Gully in south-central part sec. 7, T. 61, R. 20, Pleasanton formation.
247. Railroad cut in N.W. ¼ sec. 22, T. 44, R. 24. Shale just above lower limestone of Fort Scott limestone member of Henrietta formation.
248. S.E. ¼ sec. 5, T. 39, R. 33, west of schoolhouse. Top of Labette shale member of Henrietta formation.
249. Shale above "10-in. cap" of Mystic coal, at bridge east of Youngstown. S.W. corner sec. 19, T. 62, R. 16. Fort Scott limestone member of Henrietta formation.
250. Quarry southeast part of Milan. Bethany Falls limestone member of Kansas City formation.
251. Strip pit north of road in S.E. ¼ N.W. ¼ sec. 33, T. 42, R. 28. Upper surface of lower limestone of Fort Scott limestone member of Henrietta formation.
252. South bank of north fork of Blackwater. West side sec. 12, T. 47, R. 28. Fort Scott limestone member of Henrietta formation.
253. East side small branch, east side of main creek on road $\frac{14}{23}$, T. 39, R. 33. Pawnee limestone member of Henrietta formation.
254. "Diamond Rock," near center of west line of sec. 26, T. 39, R. 32. In old cut. Cherokee shale, 70 feet more or less below top.
255. South of Rich Hill, Mo. Horizon just above Rich Hill thick coal. Cherokee shale, 150 feet more or less below top.
255a. South of Rich Hill, Mo. From horizon just above thick coal. Cherokee shale, 150 feet more or less below top.
256. Mendota, Mo. Cap rock of Mystic-Mendota coal. Mine No. 9. Fort Scott limestone member of Henrietta formation.
257. Near Carey strip pit, 1½ miles east of Harrisburg, Mo. Cherokee shale, near Bevier coal horizon.
258. On Chariton River, northest of Keytesville. From rocks associated with coal mined at Dooley and Cooley mines. Cherokee shale, near Bevier coal sump rock.
259. Cap rock of Mystic bed. Dump of Big Jim mine, Seymour, Iowa. Fort Scott limestone member of Henrietta formation.
260. N.E. ¼ N.E. ¼ sec. 10, T. 52, R. 21. Two miles southeast of Miami, Mo. From rocks above thin coal formerly mined. Cherokee shale, near local base.
261. Dump of Trenton Mining Co. Cherokee shale, about 100 feet below top. Lower Ardmore coal horizon.
262. Weston Coal & Mining Company's south mine, 4 miles south of Lexington, Mo. From the "Sulphur" immediately underlying the Lexington coal bed, in the Cherokee shale.
263. One mile west of Novinger, Mo. In railroad cut, 10 feet above track. In light drab shale that lies under 1 foot of slate that is 45± feet below the Mystic-Stahl coal. Cherokee shale, Summit coal.

264. Swanwick mine, Swanwick, Ray Co., Mo. From dump. Fort Scott limestone member of Henrietta formation.
265. N.E. 1/4 sec. 33, T. 40, R. 33. Near Amoret, Bates Co., Mo. Pleasanton formation from shale, just above Mulberry coal, material corresponds to Bandera shale of Kansas.
266. One mile southwest of Hams Prairie, Callaway Co., Mo. Cherokee shale, at local base.
267. One half mile east of Pickel sandstone quarry, northeast of Warrensburg, Mo. Cherokee shale, Mulky coal?, 80 feet from top of Cherokee.
268. Two miles north of Knobnoster, Mo. Cherokee shale, impure limestone above Bevier coal.
269. Gooding strip pit, 1½ miles north of Hinton, Boone Co., Mo. Cherokee shale, in slate and "cap rock" of Mulky coal bed.
270. Silver Creek, due west of Hallsville, Mo. Cherokee shale, in cap rock of Mulky coal bed.
271. Leavenworth quadrangle, Leavenworth, Kansas. Cherokee shale, from above coal mined by Home-Riverside Coal Company, the Bevier coal.
272. Leavenworth quadrangle, N.E. corner sec. 19, T. 54, R. 36. Upper limestone of Oread limestone member of Douglas formation.
273. Leavenworth quadrangle, upper limestone of Oread limestone member of Douglas formation, in quarry northwest corner sec. 27, T. 8 S., R. 22 E. One mile northwest of Leavenworth.
274. Leavenworth quadrangle. West side of Owl Creek in road in sec. 35, T. 54, R. 35. Iatan limestone member of Douglas formation.
275. Leavenworth quadrangle. Platte River bridge, sec. 34, T. 52, R. 35. Lane shale member of Lansing formation, just below Farley limestone bed.
276. Leavenworth quadrangle. Same as 276a. Iatan limestone member of Douglas formation.
276a. Leavenworth quadrangle. Bluff ½ mile north of depot at Weston, Mo. Near base of Lawrence shale member of Douglas formation.
276b. Same as 276a. Near base of Lawrence shale member of Douglas formation.
277. Leavenworth quadrangle. Southwest corner sec. 15, T. 53, R. 35. Top of Stanton limestone member of Lansing formation.
278. Leavenworth quadrangle. Wagon road south of Iatan. Near base of Lawrence shale member of Douglas formation.
279. Leavenworth quadrangle. Cut in sec. 19, T. 53, R. 35. Upper limestone of Stanton limestone member of Lansing formation.
279a. Same as 279. Leavenworth quadrangle. Lower limestone of Stanton limestone member of Lansing formation.
280. Leavenworth quadrangle. N.E. 1/4 N.W. 1/4 sec. 11, T. 51, R. 35. Plattsburg limestone member of Lansing formation.
281. Leavenworth quadrangle. Southwest corner sec. 2, T. 53, R. 36, in quarry in Iatan limestone member of Douglas formation.
282. Leavenworth quadrangle. N.E. 1/4 N.W. 1/4 sec. 16, T. 52, R. 35. Near base of Lawrence shale member of Douglas formation.
283. Leavenworth quadrangle. Near base of Lawrence shale member of Douglas formation near Leavenworth.
284. Leavenworth quadrangle. Northeast corner sec. 13, T. 54, R. 36, 1½ miles north of Iatan. Upper limestone of Oread limestone member of Douglas formation.
285. Leavenworth quadrangle. East bank of Platte River, near river bridge in sec. 34, T. 52, R. 35. From Broadhead's No. 100. Middle of Lane shale member of Lansing formation, in the Farley limestone bed.

285a. Leavenworth quadrangle. East bank of Platte River near river bridge in sec. 23, T. 52, R. 35. From Broadhead's 100. Middle of Lane shale member of Lansing formation in the Farley limestone bed.

286. Leavenworth quadrangle. Clay pit at Kansas State Penitentiary, Lansing, Kansas. Lane shale member of Lansing formation above Farley limestone bed.

287. Leavenworth quadrangle. Coal mine at Kansas State Penitentiary, Lansing, Kansas. Cherokee shale, 85 feet ± below top, near Bevier coal.

288. Leavenworth quadrangle. Southeast corner sec. 12, T. 54, R. 36, 1½ miles north of Iatan. Lecompton limestone member of Shawnee formation.

289. Leavenworth quadrangle. N.W. ¼ sec. 29, T. 54, R. 36. Missouri River bluffs ¾ mile south of Iatan. Iatan limestone member of Douglas formation.

290. Leavenworth quadrangle. Kansas State Penitentiary quarry, Lansing, Kansas. S.W. ¼ N.E. ¼ sec. 19, T. 9 S., R. 23 E. Main ledge of upper limestone of Stanton limestone member of Lansing formation.

290a. Leavenworth quadrangle. Kansas State Penitentiary quarry, Lansing, Kansas. S.W. ¼ N.E. ¼ sec. 19, T. 9 S., R. 23 E. Lower limestone of Stanton limestone member of Lansing formation.

291. Leavenworth quadrangle. Hillside, northeast corner sec. 27, T. 8 S., R. 22 E. Lower limestone of Oread limestone member of Douglas formation.

292. Leavenworth quadrangle. Roadside on Government Hill, N.W. ¼ sec. 22, T. 8 S., R. 22 E. Middle of Oread limestone member of Douglas formation.

293. Leavenworth quadrangle. Roadside on Government Hill in N.W. ¼ sec. 22, 8 S., R. 22 E. Lower Oread limestone member of Douglas formation.

294. Leavenworth quadrangle, at Fort Bridge at Fort Leavenworth. Iatan limestone member of Douglas formation.

295. Leavenworth quadrangle. Seven-mile Creek, ¾ mile above mouth, Lansing, Kansas. S.W. ¼ S.W. ¼ sec. 18, T. 9 S., R. 23 E. Plattsburg limestone member of Lansing formation.

296. Leavenworth quadrangle. Nine-mile Creek, near mouth. N.W. ¼ N.W. ¼ sec. 20, T. 9 S., R. 23 E., Lansing, Kansas. Plattsburg limestone member of Lansing formation.

297. Leavenworth quadrangle, pit of Leavenworth Vitrified Brick Co. N.W. ¼ S.E. ¼ sec. 1, T. 9 S., R. 22 E. Weston shale member of Douglas formation.

298. Leavenworth quadrangle. Bluff of Missouri River, just north of Weston, Mo. Lower part of Lawrence shale member of Douglas formation.

299. Leavenworth quadrangle. Northwest corner of sec. 33, T. 54, R. 36. Missouri River bluffs, 2 miles south of Iatan. Lawrence shale member of Douglas formation, near base.

300. Leavenworth quadrangle. Along bluff road, ¼ to ½ mile north of Iatan. Lower part of Lawrence shale member of Douglas formation.

301. Leavenworth quadrangle. At Fort Bridge, Fort Leavenworth, Kansas. Upper part of Weston shale member of Douglas formation, just below Iatan limestone member.

302. Leavenworth quadrangle. Southwest corner sec. 24, T. 54, R. 35. Iatan limestone member of Douglas formation.

303. Leavenworth quadrangle. Roadside on Government Hill, N. W. ¼ sec. 22, T. 8 S., R. 22 E. Shale immediately below middle limestone of Oread limestone member of Douglas formation.

304. Leavenworth quadrangle, N.E. ¼ S.W. ¼ sec. 24, T. 54, R. 35. Iatan limestone member of Douglas formation.

305. Leavenworth quadrangle. Old brick shale pit, N.W. ¼ N.E. ¼ sec. 19, T. 9 S., R. 23 E., Lansing, Kansas. Lower limestone of Stanton limestone member of Lansing formation.

306. Leavenworth quadrangle. Same as 279, Stanton limestone member of Lansing formation, in shale on lower side of lower ledge.

307. Three miles southwest of Wellsville, Montgomery Co., Mo. Cherokee shale, Mulky cap rock.

307a. Wellsville, Mo. 1½ miles south of town. Small quarry ¼ mile southwest (?) of Whitehead mine. Mostly top of limestone and shaly beds next above, in Cherokee shale, above Mulky cap rock.

307b. Wellsville, Mo., 1-1¼ miles south of town. Various small outcrops in vicinity of Whitehead mine. Shaly beds above main limestone, in Cherokee shale, above Mulky cap rock.

308. Trenton, Mo. East of bridge at south side of town, on north bluff of river. Pawnee limestone member of Henrietta formation.

309. Roadside, just south of Chariton River in S.E. ¼ sec. 35, T. 53, R. 17. Cherokee shale, Bevier sump rock.

310. Woodland Mill, Linn Co., Mo. Sec. 14, T. 57, R. 21. Labette shale member of Henrietta formation.

310a. Same as 310. Southernmost limestone. Pawnee limestone member of Henrietta formation.

413. Kansas City, Mo. West bluff. S.E. ¼ sec. 7, T. 49, R. 33. Chanute shale member of Kansas City formation.

414. Kansas City, Mo. Quarry near Brook St. and Benton Place. "Calico ledge" (Raytown limestone bed), in Chanute shale member of Kansas City formation.

415. Kansas City, Mo. S.E. ¼ sec. 6, T. 49, R. 33. West Bluff. Drum limestone member of Kansas City formation.

416. Kansas City, Mo. N.E. ¼ sec. 9, T. 49, R. 33, "Building ledge" (Cement City limestone bed), in Chanute shale member of Kansas City formation.

417. Kansas City, Mo., 12th St. and W. Bluff, sec. 6, T. 49, R. 33. "Calico ledge" (Raytown limestone bed), in Chanute shale member of Kansas City formation.

418. Kansas City, Mo. From a nodule in the shale at the top of the Chanute shale member of the Kansas City formation. Quarry on West Bluff just above the Turkey Creek pumping station.

419. Kansas City, Mo. S.W. ¼ sec. 7, T. 49, R. 33. Top of Bethany Falls limestone member of Kansas City formation.

420. Kansas City, Mo. Penn Valley Park. Broadhead's limestone No. 100. Farley limestone bed, in Lane shale member of Lansing formation.

421. Kansas City, Mo. N.W. ¼ sec. 7, T. 49, R. 33. Bottom of Iola limestone member of Kansas City formation.

422. Kansas City, Mo. Corner Belleview & Kansas Boulevards, sec. 18, T. 49, R. 33. Raytown limestone bed, in Chanute shale member of Kansas City formation.

423. Kansas City, Mo. Kansas City Southern Ry., east of Zoo, in Swope Park. Broadhead's limestone 74. Hertha limestone member of Kansas City formation.

424. Kansas City, Mo. Sec. 18, T. 49, R. 33, corner of Madison and 29th St. Cement City limestone bed, in Chanute shale member of Kansas City formation.

425. Kansas City, Mo. N.W. ¼ sec. 7, T. 49, R. 33. Chanute shale member of Kansas City formation, in Raytown limestone bed and overlying shale at top of Chanute member.

426. Kansas City, Mo. S.E. ¼ sec. 29, T. 49, R. 33. Broadhead's 85a. Winterset limestone member of Kansas City formation.

429. Kansas City, Mo., 6th and Bluff streets, oölite bed. Drum limestone member of Kansas City formation.

429a. Same as 429. Kansas City formation, in heavy limestone above the oölite. Chanute shale member; may be Iola limestone member.

430. Chillicothe, Mo. Livingston Co. Pleasanton formation near base, probably above the unconformity.
435. Vandalia, Mo. Limestone about 8-12 feet above the lowest coal. Cherokee shale, limestone over Mulky coal.
644. Kansas City quadrangle. Corner Prospect Ave., and Swope Parkway, Kansas City, Mo. Cherryvale shale member of Kansas City formation, 12 feet above Winterset limestone member.
645. Sperry Quarry at Bethany, Mo. Winterset limestone member of Kansas City formation.
646. 2½ miles east of Gilman City, Mo. Winterset limestone member of Kansas City formation.
647. Green City quadrangle. Sec. 32, T. 65, R. 17. Pleasanton formation (above unconformity?).
648. Green City quadrangle. Sec. 19, T. 64 N., R. 18 W. Pleasanton formation near base. (Near unconformity).
649. Queen City quadrangle. In black shale at "slate ford," S.W. ¼ S.W. ¼ sec. 22, T. 65, R. 16. Cherokee shale, Bevier coal horizon.
650. Leavenworth quadrangle. On first hill east of Platte City, Mo. Base of Iatan limestone member of Douglas formation.
651. Smithville quadrangle. Northwest corner sec. 7, T. 52, R. 31, 4 miles southeast of Platte City, Mo. Base of Iatan limestone member of Douglas formation.
652. Leavenworth-Smithville quadrangle. Northwest corner of sec. 7, T. 52, R. 31. Four miles southeast Platte City, Mo. Nodule in Weston shale member of Douglas formation.
653. Green City quadrangle. Sec. 19, T. 64, R. 18. Pleasanton formation near base.
654. Green City quadrangle. Sec. 19, T. 64, R. 18, Pleasanton formation near base.
655. Green City quadrangle. Sec. 5, T. 64, R. 18. Pleasanton formation near base.
656. Smithville quadrangle. Sec. 22, T. 53, R. 33. Just west of Smithville. From lowest layer of Raytown limestone bed in Chanute shale member of Kansas City formation.
657. Smithville quadrangle. Sec. 28, T. 53, R. 33, about 1½ miles southwest of Smithville. Farley limestone bed, in Lane shale member of Lansing formation.
658. Smithville quadrangle. Where road crosses creek in N.E. ¼ sec. 32, T. 54, R. 33. Farley limestone bed, in Lane shale member of Lansing formation.
659. Smithville quadrangle. N.E. ¼ sec. 33, T. 54, R. 33. Plattsburg limestone member of Lansing formation.
660. Cunningham stripping in Fort Scott coal cap rock, N.E. ¼ N.W. ¼ sec. 15, T. 46, R. 27. Lower Fort Scott limestone member of Henrietta formation.
661. Green City quadrangle. Fort Scott limestone member of Henrietta formation and Cherokee shale above Lexington (Mystic) coal, N. E. ¼ S. E. ¼ sec. 11, T. 65, R. 17.
662. Green City quadrangle. N. E. ¼ S. E. ¼ sec. 11, T. 65, R. 17. Fort Scott limestone member of Henrietta formation.
663. Smithville quadrangle. Sec. 19, T. 54, R. 33. Farley limestone bed in Lane shale member of Lansing formation.
664. Green City quadrangle. S.W. ¼ N.W. ¼ sec. 32, T. 65, R. 17. Pleasanton formation (above unconformity?), from black slaty shale under Chariton conglomerate.
665. Green City quadrangle. N.E. ¼ S.W. ¼ sec. 31, T. 65, R. 17. Pleasanton formation, near base (northern Missouri, above unconformity).

666. Green City quadrangle. N.W. ¼ N.W. ¼ sec. 5, T. 64, R. 17, at roadside. Fort Scott limestone member of Henrietta formation.
667. Green City quadrangle. S.E. ¼ N.W. ¼ sec. 32, T. 65, R. 17. Fort Scott limestone member of Henrietta formation.
668. Green City quadrangle. South bank of Spring Creek, S.E. ¼ N.W. ¼ sec. 31, T. 64, R. 17. Cherokee shale, Summit coal horizon.
669. Green City quadrangle. East side of branch in S.E. ¼ S.W. ¼ sec. 27, T. 64, R. 18. Fort Scott limestone member of Henrietta formation. (Mystic coal cap rock).
670. South part of Novinger, Mo. Cherokee shale, limestone below Summit coal horizon.
671. Green City quadrangle. Branch on line S.W. ¼ S.E. ¼ sec. 34, T. 64, R. 18, on side of hollow. Pleasanton formation (near base).
672. Green City quadrangle. West side of hollow S.E. ¼ S. W.¼ sec. 19, T. 64, R. 18. Pleasanton formation (near base).
673. Green City quadrangle. Limestone in Pleasanton formation (near base), about 20 feet above Pawnee limestone member of Henrietta formation.
674. Green City quadrangle. S.E. ¼ N.E. ¼ sec. 28, T. 64, R. 18. Fort Scott limestone member of Henrietta formation.
675. Green City quadrangle. N.E. ¼ N.W. ¼ sec. 22, T. 64, R. 18, west side North Spring Creek. Pleasanton formation, near base.
676. Smithville quadrangle. Road in N.E. ¼ N.W. ¼ sec. 20, T. 53, R. 32. Bottom layer of Iola limestone member of Kansas City formation.
677. Smithville quadrangle. Road in N.E. ¼ N.E. ¼ sec. 18, T. 53, R. 32. Farley limestone bed, in Lane shale member of Lansing formation.
678. Smithville quadrangle. In branch N.E. ¼ N.E. ¼ sec. 26, T. 53, R. 33. Lower layer of Iola limestone member of Kansas City formation.
679. Smithville quadrangle. In branch N.E. ¼ N.E. ¼ sec. 26, T. 53, R. 33. Iola limestone member of Kansas City formation, in second layer from bottom.
680. Smithville quadrangle. South part of Smithville, S.W. ¼ S.W. ¼ sec. 23, T. 53, R. 33. Plattsburg limestone member of Lansing formation.
681. Smithville quadrangle. Bed of creek, S.E. ¼ S.E. ¼ sec. 22, T. 53, R. 33. Chanute shale member of Kansas City formation.
682. Smithville quadrangle. S.W. ¼ N.W. ¼ sec. 8, T. 51, R. 32, at roadside. From Broadhead's 107. Plattsburg limestone member of Lansing formation.
683. Smithville quadrangle. S.E. ¼ N.E. ¼ sec. 8, T. 51, R. 32, Broadhead's 96 ("Calico ledge"). Raytown limestone bed, in Chanute shale member of Kansas City formation.
684. Smithville quadrangle. Bed of creek N.W. ¼ sec. 36, T. 53, R. 33. Iola limestone member of Kansas City formation.
685. Smithville quadrangle. Roadside S.E. ¼ S.E. ¼ sec. 12, T. 54, R. 33. Plattsburg limestone member of Lansing formation.
686. Smithville quadrangle. Bank of Smith's Fork, Platte River, near line between secs. 19 and 30, T. 54, R. 32. Farley limestone bed in Lane shale member of Lansing formation.
687. Smithville quadrangle. N.E. ¼ N.W. ¼ sec. 4, T. 53, R. 32. Plattsburg limestone member of Lansing formation.
688. Smithville quadrangle. River bank S.E. ¼ S.E. ¼ sec. 19, T. 54, R. 32. Farley limestone bed, in Lane shale member of Lansing formation.
689. Smithville quadrangle. Railroad cut on line $\frac{22}{27}$ T. 53, R. 34. Vilas shale member of Lansing formation.
690. Smithville quadrangle. Bed of creek S.E. ¼ S.E. ¼ sec. 10, T. 52, R. 34. Broadhead's No. 115. Upper layer of Stanton limestone member of Lansing formation.

691. Smithville quadrangle. Bed of creek, S.E. ¼ S.E. ¼ sec. 10, T. 52, R. 34 Broadhead's No. 115. Upper layer of Stanton limestone member of Lansing formation.

692. Smithville quadrangle. Bed of creek, S.E. ¼ S.E. ¼ sec. 10, T. 52, R. 34 Broadhead's No. 115. Upper layer of Stanton limestone member of Lansing formation.

707. Woodland Mills, N.E. ¼ sec. 14, T. 57, R. 21, 4 miles southwest of Laclede, Mo. Probably Henrietta formation.

708. Round Mound, sec. 16, T. 33, R. 32, ¾ mile northwest of Verdella, Barton Co., Mo. Rock over coal bed. Cherokee shale, about 80 feet from top.

1254. Higginsville, Lafayette Co., Mo. Fort Scott limestone member (?) of Henrietta formation.

1254B. 3 miles southeast of Higginsville, Lafayette Co., Mo., on road in S.E. ¼ N.W. ¼ sec. 15, T. 49, R. 25, Fort Scott limestone member (?) of Henrietta formation.

1255A_2 Higginsville, Lafayette Co., Mo., Rocky Branch, 2½ miles west of town. Cherokee shale, near Summit coal (?).

1255A_4 Same as 1255A_2 but just above it stratigraphically. Black shale graduating above into thin limestone. Cherokee shale, near Summit coal (?).

1255B_3 Higginsville, Lafayette Co., Mo. Hard yellow concretionary limestone in branch at roadside in N. E. ¼ S.W. ¼ sec. 7, T. 49, R. 26. Pawnee limestone member of Henrietta formation.

1256A_1 Higginsville, Lafayette Co., Mo. Soft limestone west side of road 4 miles south of Dover. Cherokee shale, probably near Macon City coal.

1256B Higginsville, Lafayette Co., Mo. East side of road 4 miles south of Dover. Cherokee shale, in cap rock over Macon City coal.

1256B_1 Higginsville, Lafayette Co., Mo., east side of road 4 miles south of Dover. Coal slates, Cherokee shale, in cap rock over Macon City coal.

1260A_1 Odessa, Lafayette Co., Mo. Blackwater Creek, 7½ miles south of Odessa. Black argillaceous shale, few fossils. Cherokee shale, near top, probably Summit coal horizon.

1260A_3 Same locality as 1260A_1, but just above it stratigraphically. Light gray heavy limestone, 16 inches thick. Cherokee shale, near top, probably Summit coal horizon.

1260A_6 Same as foregoing, but 20 feet above it stratigraphically. Cherokee shale, near top, probably Summit coal horizon.

1263A_3 Clinton, Henry Co., Mo., at Jackson's mill on Grand River. Cherokee shale, not far above base.

1263A_4 Same locality as 1263A_3 and just above it stratigraphically, Cherokee shale, not far above base.

1263B_4 Clinton, Henry Co., Mo. Gilkerson Ford Bridge on Grand River, south of Clinton. Four feet of irregularly bedded sandstone, and limestone nodules. Cherokee shale, not far above base.

1263C_1 Clinton, Henry Co., Mo. old Jordan coal bank, center sec. 25, T. 41, R. 26. Yellow sandy shale 40 feet above top of Boone as seen in shaft. Cherokee shale, not far above base.

1263C_3 Same as 1263C_1, but 3 feet higher in the section. Cherokee shale, not far above base.

1263C_3+ Same locality. Cherokee shale, not far above base.

1263C_4 Same locality as 1263C_3, but 3 feet higher in the section. 3 feet blue gray shales. Cherokee shale, not far above base.

1266A_1 Lexington, Lafayette Co., Mo. River bluff below water-works. 30 feet gray limestone, upper part shaly, Henrietta formation.

1266A_2 Same locality. Ten feet higher in section, in 6 feet heavy gray limestone, Henrietta formation.

1268A_2 Garland, Henry Co., Mo. On Honey Creek in S.W. ¼ S.W. ¼ sec. 36, T. 43, R. 27. 2 feet limestone, many fossils. Cherokee shale, 100 feet ± below top. Here are also included some unlabeled or partially labeled fossils showing the same fauna.

1268B_4 Garland, Henry Co., Mo. On Honey Creek at mouth of Cottonwood Creek, in N.E. ¼ S.W. ¼ sec. 36, T. 43, R. 27. 1 foot iron bed, full of fossils, Cherokee shale, 100 feet± below top.

1268C_1 Garland, Henry Co., Mo. On Honey Creek above Buck Ford and above mouth of Cottonwood Creek in S.W. ¼ N.E. ¼ sec. 36, T. 43, R. 27. Two feet shaly limestone with fossils, Cherokee shale, 100 feet± below top.

1268D_2 Garland, Henry Co., Mo. Gray farm in S.E. ¼ N.W. ¼ sec. 29, T. 43, R. 27. 1 foot shaly limestone with fossils, Cherokee shale near top.

1269A_6 Calhoun, Henry Co., Mo. Railroad cut at station in N.W. ¼ N.E. ¼ sec. 36, T. 43, R. 25. Six inches of iron ore with fossils, Cherokee shale 100 feet± below top.

PLATE XXVII.

PLATE XXVII.

Batostomella greeniana (p. 326).

Figs. 1 and 1a. Two tangential sections from the same specimen, x 20. These show the circular zooecia and the numerous and crowded acanthopores. There are two kinds of acanthopores but they are not very conspicuous in the sections and somewhat less distinct in the illustrations. The acanthopores are in one section so crowded that they are flattened and deformed.

1b and 1c. A transverse and a longitudinal section from the same specimen as the foregoing, x 20. These show the punctate character of the wall contiguous to the zooecial tubes. These punctae are represented as smaller and more numerous than in the specimen itself. A row of them is sometimes seen down each side of a zooecium, as in fig. 1b, top. One or two diaphragms, or what appear to be such are also shown.

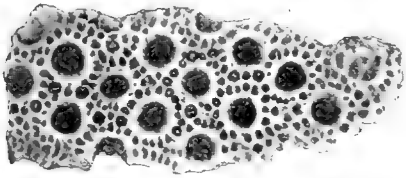
Topeka limestone, big quarry below Curzon (Station 180).

Liopora subnodosa (p. 341).

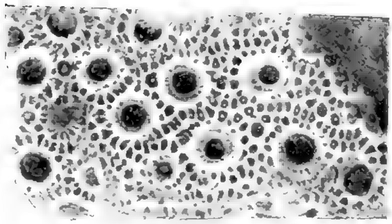
Fig. 2. A colony nearly covering the dorsal valve of a specimen of *Composita subtilita*, x 2. This figure shows the zooecial apertures and the low monticules on which no zooecia are found. The small mesopores that occur between the zooecia and occupy the monticules entirely are too small to appear in this magnification.

2a. Part of the surface, x 8. This shows the zooecia and the rows of mesopores. surrounding them, and also two monticules composed entirely of mesopores. Both zooecia and mesopores are open at the surface. Many of the zooecia have a spine-like projection from one side which gives them a lunate shape. This is shown in a number of the apertures in this figure.

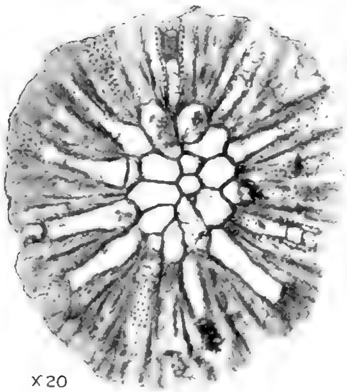
Fort Scott limestone, at bridge east of Youngstown, Mo. (Station 249).



x 20 1



x 20 1a

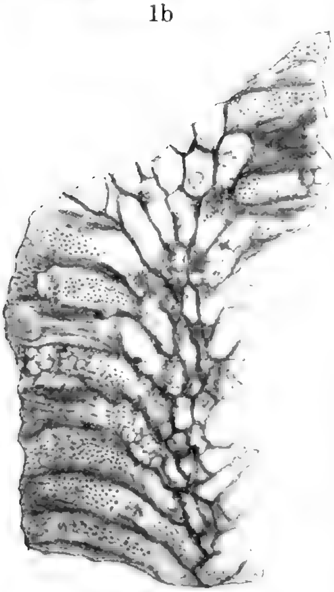


x 20

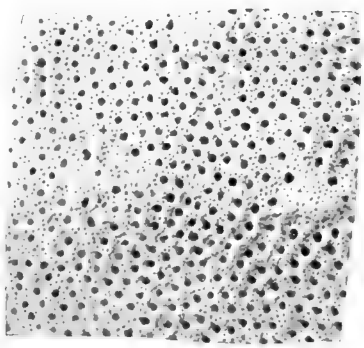
1b

x 2

2



1c



x 8 2a

PLATE XXVIII.

PLATE XXVIII.

Liopora subnodosa (p. 341).

Fig. 1. A tangential section from the same specimen shown on plate I, figs. 2 and 2a, x 20. The tangential section shows the subcircular zooecia separated by one, two, or more rows of more or less angular mesopores. A few of the zooecia have the peculiar projecting angle of the wall that gives these colonies a superficial resemblance to a very fine Fistulipora.

1a. A longitudinal section from the same specimen as the foregoing and the same shown on plate I, figs. 2 and 2a, x 20. This shows the zooecia and mesopores, entirely without diaphragms, and the slightly thickened or moniliform walls. Fort Scott limestone, at bridge east of Youngstown, Mo. (Station 249).

2. Tangential section from another specimen, x 20. In this section the projecting angles that indent the zooecial tubes are more numerous and more distinct than in fig. 1. A slight difference in thickness of the walls is also shown.

2a. Longitudinal section from the same specimen, x 20. This section shows very clearly the moniliform character of the walls and the zooecia and mesopores both devoid of diaphragms.
Upper Oread limestone, in quarry in northwest corner sec. 27, T. 8 S., R. 22 E. (Station 273).

Conocardium missouriensis (p. 353).

Fig. 3. Left valve, x 4.

3a. Same in outline, natural size.

3b. Right valve, x 4.

3c. Cardinal view, in outline.
Drum limestone, Kansas City, Mo. (Station 429).

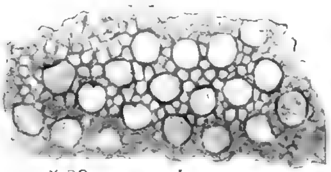
Astartella compacta (p. 354).

Fig. 4. A right valve, x 2.

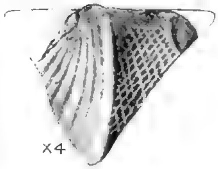
4a. Same in outline, natural size.
Cherokee shale, Garland, Henry Co., Mo. (Station 1268 A).

5. A somewhat more elongated left valve, x 2.

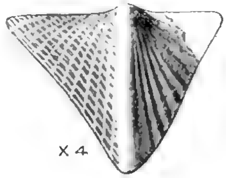
5a. Same in outline, natural size.
Cherokee shale, Garland, Henry Co., Mo. (Station 1268 A x).



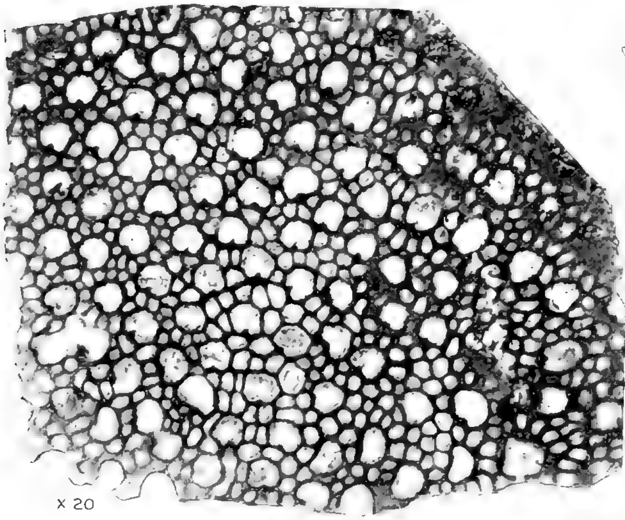
× 20 1



× 4 3



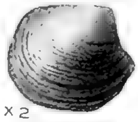
× 4 3b



× 20 2

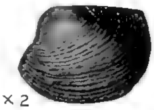
3a

3c

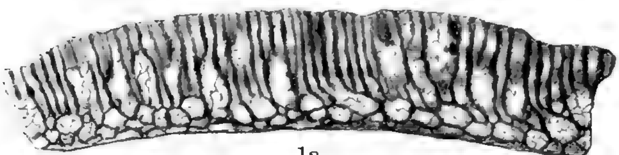


× 2 4

4a

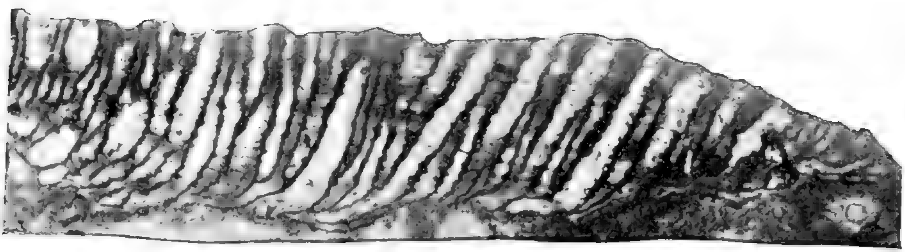


× 2 5



× 20 1a

5a



× 20 2a

PLATE XXIX.

PLATE XXIX.

Fistulipora zonata (p. 322).

Fig. 1. A thin section cutting the zooecia lengthwise, x 5. This figure shows the zooecia and thin diaphragms together with the intervening cysts in one or more rows. The banded appearance is also shown, due to the occurrence of shallow cysts along certain well defined zones.

2. Tangential section from another specimen, x 15. The figure shows the zooecia with weakly developed lunarium, separated by one or more rows of subangular cysts. The structure in the lower left hand corner is hard to interpret. The central opening resembles the zooecia round about but the concentrically arranged cystose plates surrounding it are something beyond the range of my experience.

Upper Oread limestone in quarry, northwest corner of sec. 27, T. 8 S , R. 22 E. (Station 273).

Naticopsis scintilla (p. 358).

Fig 3. Side view, opposite the aperture, x 4.
3a. Same in outline, natural size.
3b. Side view (apertural) x 4.
3c. Outline of same, seen from above, x 4.
Drum limestone, Kansas City, Mo. (Station 429).

Bulimorpha minuta (p. 362.)

Fig. 4. Side view of an average specimen, x 3.
4a. Same in outline, natural size.
4b. Opposite side, x 3.
Cherokee shale, Garland, Henry Co., Mo. (Station 1268 A-2).

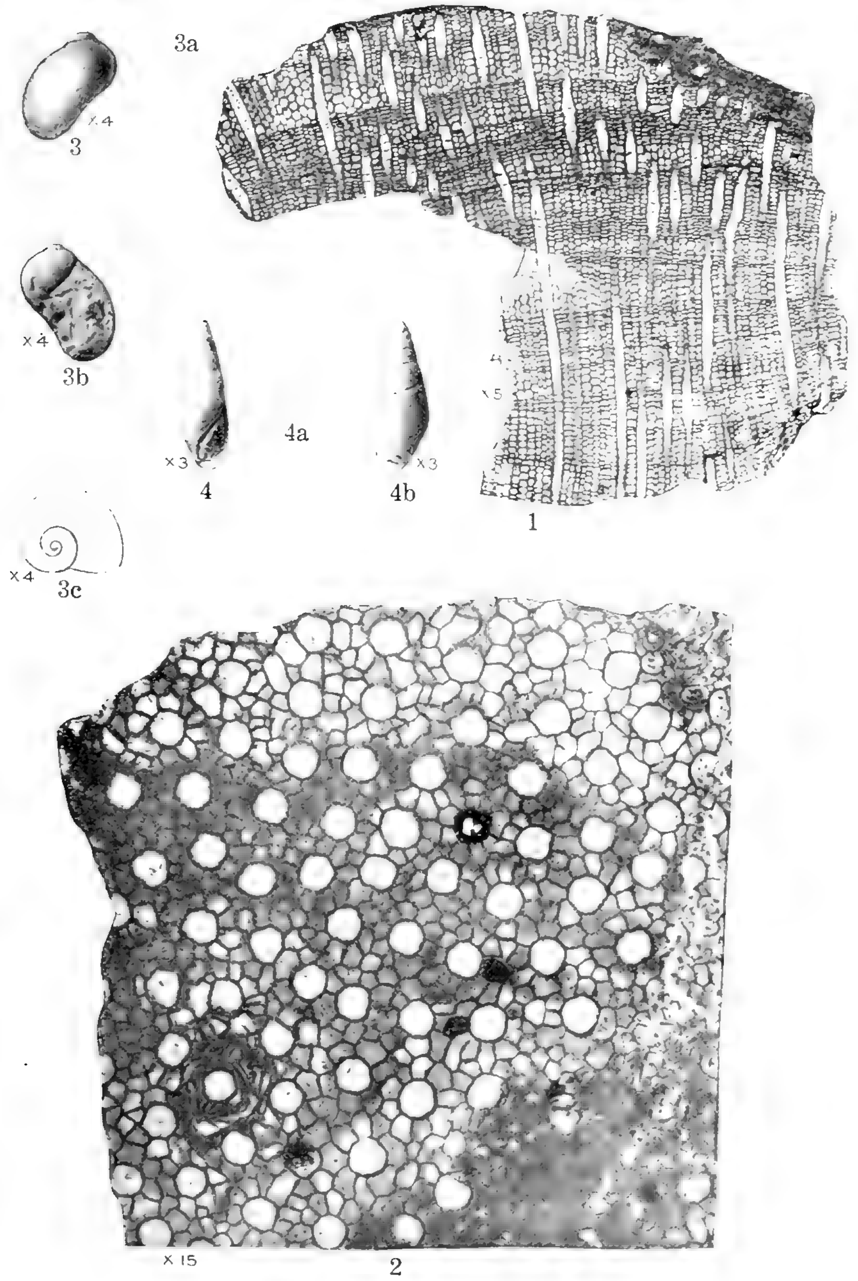

3a
x4
3
x4
3b
x3
4
4a
x3
4b
x5
1
x4
3c
x15
2

PLATE XXX.

PLATE XXX.

Ambocoelia lobata (p. 351).

Fig. 1. Dorsal view of the typical and only specimen, x 2.
1a. Same in outline, natural size.
1b. Side view, x 2.
1c. Ventral view, x 2.
1d. Same in outline, natural size.
Lecompton limestone, north central part of sec. 11, T. 59, R. 37 (Station 183).

Marginifera muricata var. missouriensis (p. 350).

Fig. 2. A characteristic ventral valve.
2a. Same, x 2.
2b. Side view in outline.
3. A ventral valve showing the not uncommon character in this species, of a fold or projection at the anterior margin.
3a. Same, x 2.
3b. Side view in outline.
4. Mold of a convex dorsal valve.
4a. Side view, in outline.
5. Mold of a shallow dorsal valve.
5a. Side view in outline.
Cherokee shale, Clinton, Henry Co., Mo. (Station 1263 C3+).

Murchisonia missouriensis (p. 355).

Fig. 6. Side view showing the aperture, which is, however, broken, x 2.
6a. Same in outline, natural size.
Cherokee shale, Garland, Henry Co., Mo. (Station 1268 A-2.)

Goniospira lasallensis (p. 356).

Fig. 7. A specimen seen somewhat obliquely on the base showing the solid columella and apparent absence of an inner lip, x 2.
8. Side view of the lower volutions of a specimen showing the growth lines which indicate the position of the slit band on the carina.
8a. Oblique view of the basal portion showing the pair of revolving ridges which look like a slit band, but are not, and a deposit which seems to be an inner lip, x 2.
Lawrence shale, near Iatan, Mo. (Station 300).

Tabulipora vera (p. 340).

Figs. 9, 9a. Two tangential sections from the same specimen, x 20. They show the rather numerous young cells, the walls, for the most part much thickened, but in places thin, and the absence of acanthopores. The dark median line of the walls is in places continuous, and in places made up of a series of granules. This is not well shown in figures of this magnification.
Bethany Falls limestone, quarry near Milan, Mo. (Station 250).

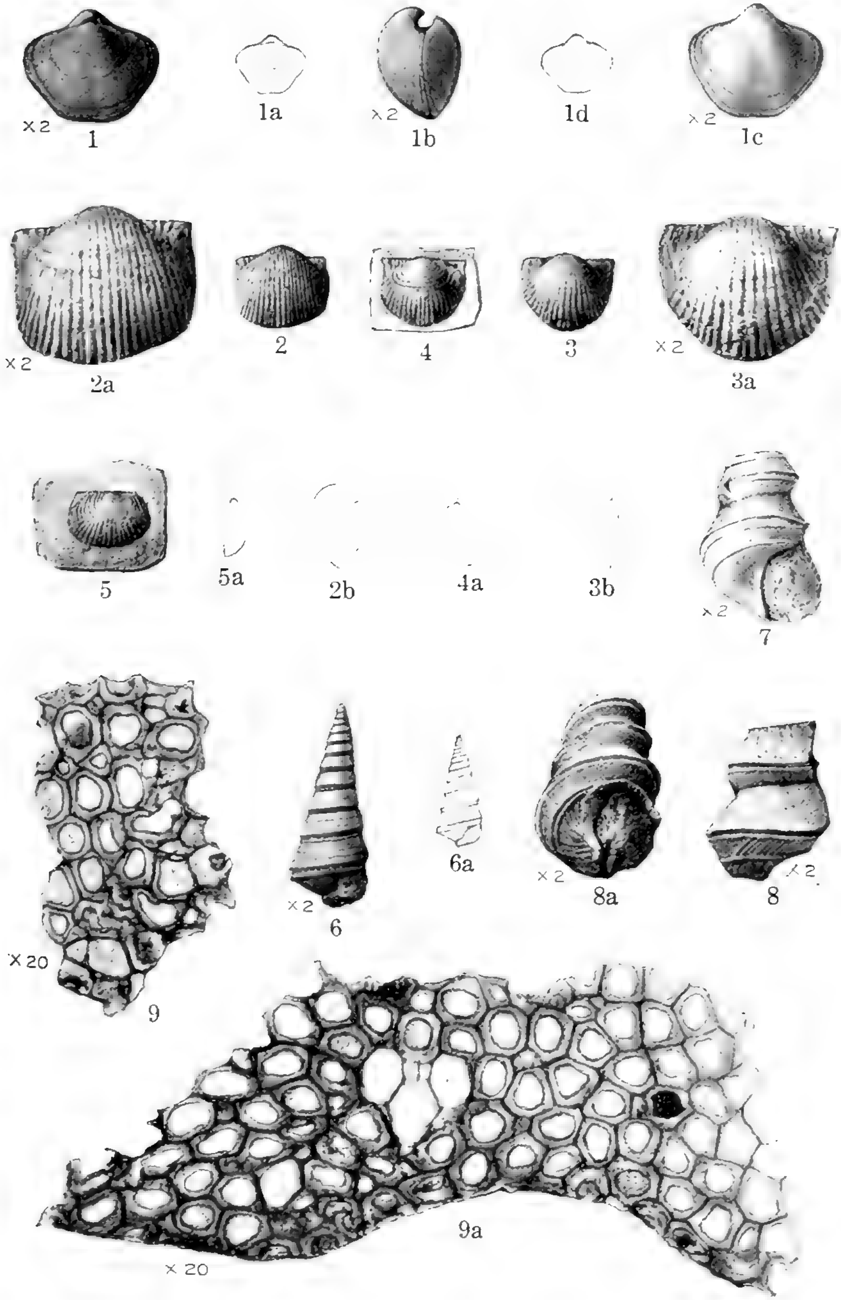

×2
1
1a
×2
1b
1d
×2
1c
×2
2a
2
4
3
×2
3a
5
5a
2b
4a
3b
×2
7
×20
9
×2
6
6a
×2
8a
×2
8
9a
×20

PLATE XXXI.

PLATE XXXI.

Leda arata (p. 351).

Fig. 1. Left valve of a characteristic specimen.
1a. Right valve.
1b. Cardinal view, x 2, showing ligamental groove.
2. Right valve of a specimen resembling the original of fig. 3.
2a. Cardinal view, x 2.
3. Right valve of a specimen having an unusual shape.
4. Right valve of a young specimen.
5. Right valve of a characteristic specimen.
5a. Cardinal view in outline.
6. Right valve of another specimen.
6a. Cardinal view, x 2.
7. Right valve of a small specimen.
7a. Left valve of same.
8. Fragment of a right valve showing the chondrophore and, somewhat broken and worn, part of the dentition, x 4.

Lawrence shale, two miles south of Iatan, Mo. (Station 299).

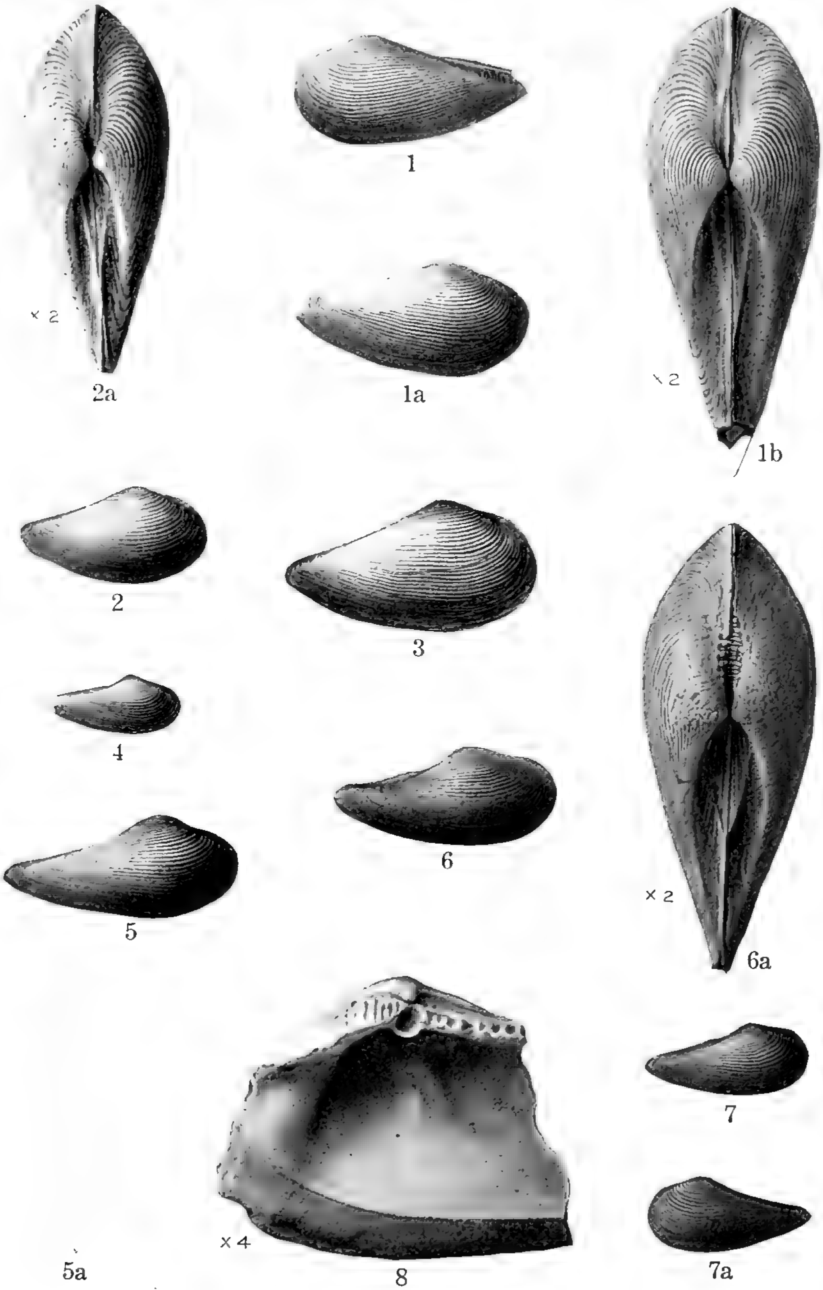

2a
×2
1
1a
1b
×2
2
3
4
5
6
6a
×2
7
7a
8
×4
5a

PLATE XXXII.

PLATE XXXII.

Pleurotomaria persimplex (p. 355).

Fig. 1. The type specimen, seen from above, x 3.
1a. Same in outline, natural size.
1b. Lower side, x 3.
1c. Side view opposite the aperture, x 3.
1d. Same in outline, natural size.
2. Upper side of another specimen, x 3.
2a. Lower side. This specimen shows part of the natural outline of the aperture which has an angular deflection and then extends obliquely forward and upward. The umbilicus is very small.
Cherokee shale, Garland, Henry Co., Mo. (Station 1268A-2).

Naticella americana (p. 359).

Fig. 3. Side view of a typical specimen, x 3.
3a. Opposite side, x 3.
3b. Seen from above, x 3.
3c. Same in outline, natural size.
Cherokee shale, Garland, Henry Co., Mo. (Station 1268A-2.)

Zygopleura teres (p. 360).

Fig. 4. Side view of the typical specimen, x 5.
4a. Opposite side, x 5.
Drum limestone, Kansas City, Mo. (Station 429).

Zygopleura nana (p. 360).

Fig. 5. Side view, x 5.
5a. Opposite side, x 5.
Drum limestone, Kansas City, Mo. (Station 429).

Zygopleura affinis (p. 359).

Fig. 6. Side view of a rather small individual, x 3.
6a. Same, natural size.
6b. Opposite side, x 3.
Cherokee shale, Garland, Henry Co., Mo. (Station 1268A-2.).

Hemizyga elegans (p. 362).

Fig. 7. Apertural view of the type specimen, x 3.
7a. Same in outline, natural size.
7b. Opposite side, x 3.
Cherokee shale, Garland, Henry Co., Mo. (Station 1268A-2.).

Hemizyga grandicostata (p. 362).

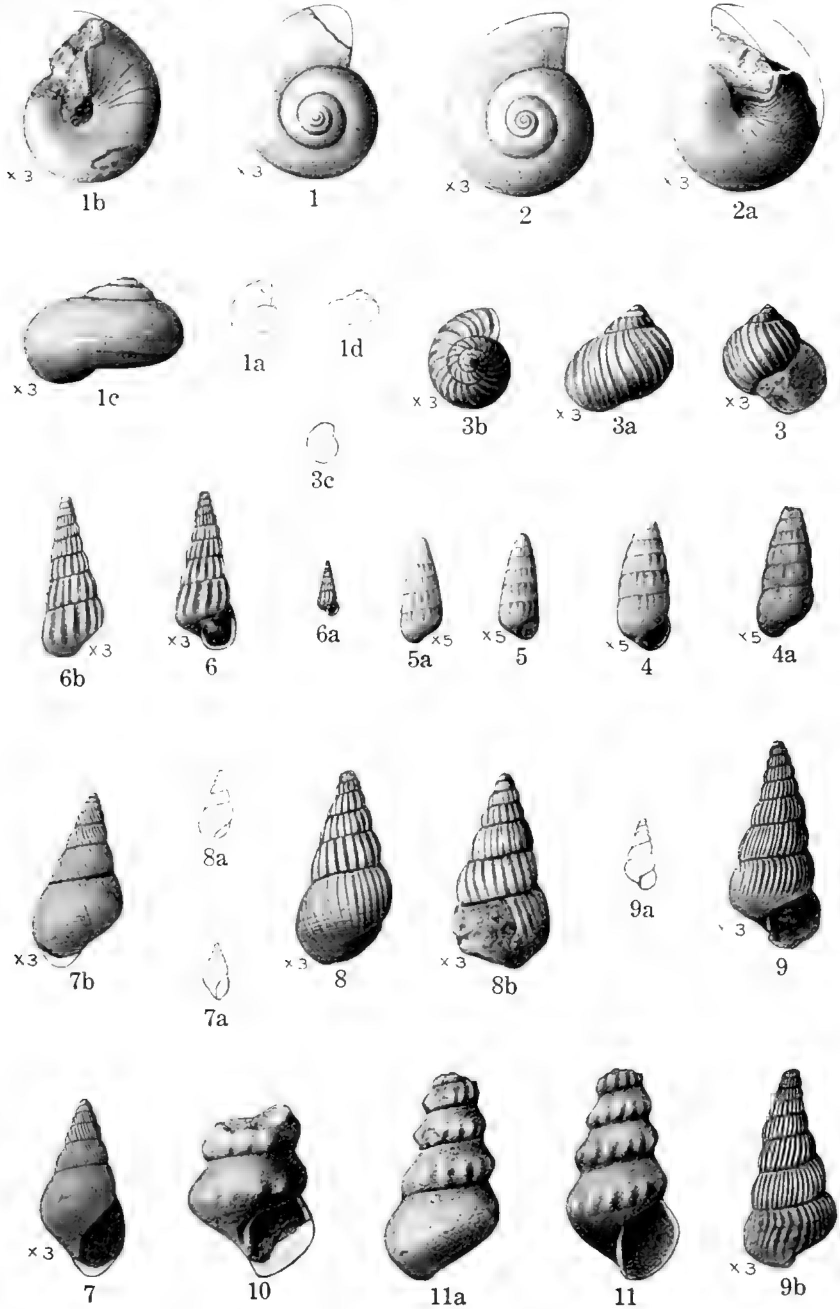
Fig. 8. Side view, x 3.
8a. Same in outline, natural size.
8b. Another side, x 3.
Cherokee shale, Garland, Henry Co., Mo. (Station 1268A-2.).

Hemizyga dubia (p. 361).

Fig. 9. Apertural view, x 3.
9a. Same in outline, natural size.
9b. Opposite side, x 3.
Cherokee shale, Garland, Henry Co., Mo. (Station 1268A-2.).

Zygopleura nodosa (p. 360).

Fig. 10. An imperfect specimen showing the true outline of the aperture, in part.
11. Apertural view of the type specimen. This specimen is imperfect below, and has been restored.
11a. Opposite side. In this view also restoration has been made in the lower part.
Calhoun shale, S.W. ¼ S.W. ¼ sec. 9, T. 59, R. 37. (Station 206).


×3
1b
×3
1
×3
2
×3
2a
×3
1c
1a
1d
×3
3b
×3
3a
×3
3
3c
×3
6b
×3
6
6a
×5
5a
×5
5
×5
4
×5
4a
×3
7b
8a
7a
×3
8
×3
8b
9a
×3
9
×3
7
10
11a
11
×3
9b

CHAPTER IX.

BIBLIOGRAPHY.

The following bibliography comprises by far the greater number of publications dealing directly with the Pennsylvanian area of Missouri and includes all, so far as known, which have a bearing on the coal deposits of the State. Short bibliographies are given under each county in the companion volume of this report[1] where most of the information concerning coal statistics and coal analyses has been tabulated.

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